8. *Method to Assess Riverine Flow-through Wetlands*

The method includes models for the following functions.

- Potential for Removing Sediment
- Potential for Removing Nutrients
- Potential for Removing Heavy Metals and Toxic Organics
- Potential for Reducing Peak Flows
- Potential for Decreasing Downstream Erosion
- Potential for Recharging Groundwater
- General Habitat Suitability
- Habitat Suitability for Invertebrates
- Habitat Suitability for Amphibians
- Habitat Suitability for Anadromous Fish
- Habitat Suitability for Resident Fish
- Habitat Suitability for Wetland-associated Birds
- Habitat Suitability for Wetland-associated Mammals
- Habitat for Native Plant Associations
- Potential for Primary Production and Organic Export

8.1 Potential for Removing Sediment — Riverine Flow-through Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

8.1.1 Definition and Description of Function

Removing sediment is defined as the wetland processes that retain sediment in a wetland, keeping it from moving to downgradient surface waters in the watershed.

A wetland performs this function if there is a net annual decrease of the amount of sediment to downgradient surface waters in the watershed. Reduction in water velocity and filtration are the major processes that remove sediment from surface water flows in riverine flow-through wetlands. When water velocity is reduced, particles present in the water will tend to settle out (Mitsch and Gosselink 1993). The size of the particles that settle out is directly related to the reduction in the velocity achieved in the wetland. Filtration is the physical blockage of sediment by erect vegetation.

8.1.2 Assessing this Function for Riverine Flow-through Wetlands

The potential of riverine flow-through wetlands to remove sediment is a function of their ability to reduce water velocities (Adamus et al. 1991). This is done by the retention time of the water they hold back and by vegetation structure near the ground surface (Adamus et al. 1991).

The removal of sediments by riverine flow-through wetlands is a more transitory process than in the other subclasses because large flooding events can re-suspend sediments and transport them out of the AU. The process of trapping sediments most of the time, however, is still judged to be an important function on a watershed scale. A riverine flow-through wetland that traps sediments most of the time (e.g. nine out of ten flood events) provides a net water quality improvement in the surface waters. This is an improvement on a temporal scale rather than on a mass balance.

Retention time cannot be estimated directly in a rapid assessment method. The path of the water through the AU, and the relative width of the AU are used as variables that capture two related aspects of reduction in velocity. The area of the AU covered by different types of vegetation classes is used as an indicator of the vegetation structure present. The area over which sediment retention occurs in this subclass is expected to be the entire AU because it is, by definition, frequently flooded.

The Assessment Team judged that riverine flow-through wetlands contained within dikes have a lower potential to trap sediments. The dikes increase the velocity of water during a flood event by constraining the flow.

8.1.3 Model at a Glance

Riverine Flow-through — Removing Sediments

Process	Variables	Measures or Indicators
Velocity reduction	**Vflowpath**	No indicator needed, variable can be measured
Velocity reduction	**Vau/stream**	Ratio of width of AU to width of stream

Filtration	**Vvegclass**	% cover in AU of forest, shrub, and emergent vegetation
Filtration	**Vunderstory**	% cover of herbaceous understory
Reducers		
Dikes	**Vdikes**	AU constrained by dikes
Index:	(Vflowpath + 2 x Vau/stream +Vvegclass + Vunderstory) x dikes / Score from reference standard site	

8.1.4 Description and Scaling of Variables

$V_{flowpath}$ – The ratio of the length of the channel or stream in the AU to the length of the AU. This variable estimates the length of time water will stay within the AU

Rationale: $V_{flowpath}$ characterizes the velocity reduction possible in an AU from the path the water takes. High ratios indicate the stream meanders through the AU and the retention time is higher. Low ratios (e.g. <1.0), on the other hand, indicate the stream or channel goes through only a small part of the AU and the water has a relatively lower retention time within the AU because much of AU may not be part of the "contact area."

Indicators: No indicators are needed. The ratio can be estimated from field or map measurements.

Scaling: AUs whose ratio is greater than or equal to 1.2 (i.e. the stream or channel is 1.2 times longer than the AU) are scored a [1] for this variable. Ratios that are less than 1.2 are scaled as ratio/1.2. . AU's that do not have a channel within their boundaries or immediately adjacent to them are scored a [0].

$V_{au/stream}$ – The ratio of the width of the AU to the width of the stream or channel in the AU.

Rationale: $V_{au/stream}$ an estimate of the relative volume of storage available in the riverine flow-through wetlands. The areas on either side of a channel provide the overflow areas that store water during flooding. AUs that are wide relative to the channel will provide more storage during a given flood event, than AUs that are narrow.

Indicators: No indicators are needed. The ratio can be estimated from field or map measurements.

Scaling: AUs whose ratio is greater than or equal to 10 (i.e. the AU is 10 times wider than its stream or channel) are scored a [1] for this variable. Ratios that are less than 10 are scaled as ratio/10.0. AU's that do not have a channel within their boundaries or immediately adjacent to them are scored a [0].

$V_{vegclass}$ – Percent of ground in an AU that is covered by each of four Cowardin (1979) vegetation classes (emergent, scrub/shrub, forest, and aquatic bed).

Rationale: Persistent plants enhance sedimentation by resisting the flow of water and thus reducing its velocity (Jackson and Starrett 1959, Karr and Schlosser 1977, see also review in Adamus et al. 1991). It is assumed that three of the four Cowardin vegetation classes (forest, shrub, and emergent) represent persistent vegetation.

Indicators: No indicators are needed. The areal extent of the three vegetation classes can be estimated directly.

Scaling: The scaling of the variable is based on the percent of the AU covered by four different vegetation classes with a scaling factor based on the type of vegetation. Emergent vegetation is assumed to provide the best sediment retention because it is usually the densest and provides the best trapping near the ground surface (relative factor = 1). Scrub/shrub vegetation is judged to provide almost as much sediment trapping and is factored at 0.8. Forests usually do not have a very high stem density near the surface and are factored at 0.3. Aquatic bed vegetation is not usually permanent and persistent, and therefore, is not expected to provide much sediment trapping. It is factored as [0]. The score for this variable is calculated as (fraction of AU with emergents x 1) + (fraction of AU with scrub/shrub x 0.8) + (fraction of AU with forest x 0.3).

$V_{understory}$ – The areal extent of herbaceous vegetation that is found under the forested and scrub/shrub areas of the AU.

Rationale: This variable was included to correct a potential error in the previous variable ($V_{vegclass}$). The Cowardin classification characterizes only the highest layer of vegetation and does not characterize the understory. AU's that are forested may still provide good sediment retention if they have an herbaceous understory. Only relatively dense areas of understory with a minimum cover of 20% are included in this variable.

Indicators: No indicators are needed. The areal extent of the herbaceous understory can be estimated directly.

Scaling: The scaling of the variable is based on the percent of the AU covered by a herbaceous understory. AU's with a 100% cover of understory over the entire unit are scaled as [1]. AU's with a cover of less than 100% are scaled proportionally as %area/100.

V_{dikes} – The AU is within the boundaries of dikes that constrain the flooding from a stream or river. This variable is used to indicate potential reductions in the level of performance for the function.

Rationale: Dikes are judged to increase the velocity of water during a flood event by constraining the flow and raising the hydraulic head. The presence of dikes is also indicative of the fact that the storage capacity of the floodplain has been reduced.

Indicators: No indicators are needed. The presence of dikes can be determined directly.

Scaling: This is an "on/off" variable. AU's that contain dikes within a distance of four channel widths of the channel itself are considered to be constrained by dikes. Such AUs have their index reduced by a factor of 0.7.

8.1.5 Calculation of Potential Performance

Riverine Flow-through – Removing Sediment

Variable	Description of Scaling		Score for Variable	Result
Vflowpath	*Highest:*	Ratio of channel distance / length of AU > =1.2	If calculation is > = 1.2, enter “1”	
	Lowest:	No channel present in AU	If D7 is 0, enter “0”	
	Calculation:	Ratio of channel distance / length of AU < 1.2	Enter result of calculation	
	Calculate D7/1.2 to get result			
Vau/stream	*Highest:*	Ratio of AU width to width of stream > = 20	If calculation > = 20, enter “2”	
	Lowest:	No stream adjacent or in the AU	If calculation = 0, enter “0”	
	Calculation:	Ratio of AU width to width of stream <20	Enter result of calculation	
	If D6/D5 < 20 calculate 2 x (D6/D5)/20 to get result			
Vunderstory	*Highest:*	100% of AU has herbaceous understory and FO + SS =100%	If calculation =100 enter “1”	
	Lowest:	No herbaceous understory in AU	If D16 = 0, enter “0”	
	Calculation:	Scaling based on understory as % of the total area of AU	Enter result of calculation	
	Calculate (0.01 x D16) x (D14.1 + D14.2 + D14.3 + D14.4)/100			
Vvegclass	*Highest:*	100% of AU has emergent class	If D14.5 = 100, enter “1”	
	Lowest:	No EM, SS, or FO vegetation present in AU	If sum (D14.1 to D14.5) = 0, enter “0”	
	Calculation:	EM veg. scaled as 1; SS as 0.8 and FO as 0.3; x the relative area of each vegetation class	Enter result of calculation	
	Calculate ((D14.5 x 1) + ((D14.3 + D14.4) x 0.8)+ ((D14.1 + D14.2) x 0.3))) x 0.01 to get result			
			Total of Variable Scores:	
Reducer				
Vdikes	AU is constrained within dikes		If D4.2 is 1, enter “0.7”	
			If D4.2 is 0, enter “1”	
			Score for Reducer:	
Index for Removing Sediment = Total for variables x reducer x 2.56 rounded to nearest 1				
			FINAL RESULT:	

8.1.6 Qualitative Rating of Opportunity

The opportunity of AU's in this subclass to remove sediment is a function of the level of disturbance in the landscape. Relatively undisturbed watersheds in the lowlands in western Washington will carry much lower sediment loads than those that have been impacted by development, agriculture, or logging practices (Hartmann et al. 1996, and Reinelt and Horner 1995). The opportunity that an AU has to remove sediment is, therefore, linked to the amount of development, agriculture, or logging present in the upgradient part of its contributing basin.

Users must make a qualitative judgement on the opportunity of the AU to actually trap sediment by considering the land uses in the contributing watershed and the condition of its buffer. The opportunity for an AU in the riverine flow-through subclass to remove sediments is **"Low"** if most of its contributing watershed is undeveloped, not farmed, or not recently logged. Densely vegetated watersheds (e.g., undisturbed forest) stabilize soils, reduce runoff velocity, and thus export less sediment (Bormann et al. 1974, Chang et al. 1983). The opportunity is **"Low"** if the AU receives most of its water from sheetflow rather than from an incoming stream, and it has a good vegetated buffer. Vegetated buffers will trap sediments coming from the surrounding landscape before they reach the AU. A buffer that is only 5 m wide will trap up to 50% of the sediment while one that is 100 m wide will trap approximately 80% of the sediments (Desbonnet et al. 1994). The opportunity is also **"Low"** if the AU receives most of its water from groundwater since this source of water does not carry any sediments.

The opportunity for the AU to remove sediments is **"High"** is the contributing watershed is mostly agricultural , or it contains recent construction, or clear-cut logging. In contrast to undisturbed watersheds, urban, agricultural, or logged watersheds have more exposed soils and thus higher sediment loadings. AU's with upgradient disturbances to the watershed will have a greater opportunity to remove sediment and improve water quality than those in undisturbed watersheds. In general, AU's that are in urban or rapidly urbanizing watersheds will usually have some on-going construction. These AUs can all be assumed to have a **"High"** opportunity for sediment removal. Some watersheds may also have a high sediment load from natural geologic processes such as landslides or avalanches. If you know that the AU is in a watershed with geologically-induced sediment loads, its opportunity should also be rated as **"High"**.

The opportunity to remove sediment is **"Moderate"** if the activities that generate sediment are a small part of the contributing watershed, or if they are relative far away from the AU. The user must use their judgement in deciding whether the opportunity is moderate or high, and document their decision on the summary page of the assessment.

8.2 Potential for Removing Nutrients — Riverine Flow-through Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

8.2.1 Definition and Description of Function

Removing Nutrients is defined as the wetland processes that remove nutrients (particularly phosphorus and nitrogen) present in surface waters. A wetland performs this function if there is a net annual decrease in the amount of nitrogen and phosphorus to downgradient waters in the watershed.

The major process by which riverine flow-through wetlands reduce nutrient loadings is through the trapping of sediment to which phosphorus is bound. Wetlands in this subclass are regularly flooded and are not expected to have accumulations of organic matter or clays. Furthermore, removal of nitrogen through nitrification and denitrification in alternating oxic and anoxic conditions is not expected to occur because the sediments are not inundated long enough to create anoxic conditions.

Plant uptake of nutrients is not modeled because nutrients taken up will be released again after a plant dies and exported through the frequent flood events that characterize this subclass. Furthermore, some species of wetland plants actually fix nitrogen (Mitsch and Gosselink 1993). Plant uptake changes the timing of nutrient release from a wetland, but it does not significantly change the net balance of nutrients coming in, and going out of, a wetland (Phipps and Crumpton 1994, and Mitsch et al. 1995).

8.2.2 Assessing this Function for Riverine Flow-through Wetlands

The potential of AUs in the riverine flow-through subclass have to remove phosphorus from incoming surface waters is modeled as their ability to trap sediments. The one variable used is the index from the function "Removing Sediments.

8.2.3 Model at a Glance

Riverine Flow-through — Removing Nutrients

Process	Variables	Measures or Indicators
Phosphorus Removal	**Ssed**	Index for Removing Sediments
	Index : Ssed	

8.2.4 Description and Scaling of Variables

S_{sed} – index for the function "Removing Sediments."

Rationale: The index is used to model the removal of phosphorus from incoming waters because much of this nutrients comes into a wetland already bound to particulate sediments (for a review see Adamus et al. 1991).

Indicators: No indicators are needed. The variable is a index for a function.

Scaling: The index scaled between 0 and 10.

8.2.5 Calculation of Potential Performance

Use index from function "Removing Sediment".

8.2.6 Qualitative Rating of Opportunity

The opportunity that a riverine flow-through AU has for removing phosphorus should be judged by the characteristics of its upgradient watershed. Relatively undisturbed watersheds in the lowlands in western Washington will carry much lower nutrient loads than those that have been impacted by development, agriculture, or logging practices (Hartmann et al. 1996, and Reinelt and Horner 1995). The opportunity that a wetland has to remove nutrients is, therefore, linked to the amount of development and agriculture present in the upgradient part of its contributing basin.

Users must make a qualitative judgement on the opportunity the AU actually has to remove nutrients by considering the land uses in the contributing watershed. The opportunity for an AU in the depressional outflow subclass to remove nutrients is **"Low"** if most of its contributing watershed is undeveloped, or not farmed.

The opportunity for the AU to remove nutrients is **"High"** if the contributing watershed is mostly agricultural.

The opportunity to remove nutrients is **"Moderate"** if the activities that generate nutrients are a small part of the contributing watershed, or if they are relative far away from the AU. The user must use their judgement in deciding whether the opportunity is moderate or high, and document their decision on the data sheet.

8.3 Potential for Removing Metals and Toxic Organic Compounds — Riverine Flow-through Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

8.3.1 Definition and Description of Function

Removing Metals and Toxic Organic Compounds is defined as the wetland processes that retain toxic metals and toxic organic compounds coming into the wetland, and keep them from going to downgradient waters in the watershed.

An AU performs this function if there is a net annual decrease in the amount of toxic metals and toxic organics flowing to downgradient waters (either surface or groundwater) in the watershed. The major processes by which wetlands reduce metals and toxic organic loadings to downgradient waters are through sedimentation of particulate metals, adsorption, chemical precipitation, and plant uptake. Metals that tend to have a high particulate fraction, such as lead (Pb), may be removed through sedimentation. Adsorption is promoted by soils high in clay content or organic matter. Chemical precipitation is promoted by wetland areas that are inundated and remain aerobic, as well as those with pH values below 5 (Mengel and Kirkby 1982). Finally, plant uptake is maximized when there is significant wetland coverage by emergent plants (Kulzer 1990).

8.3.2 Assessing this Function for Riverine Flow-through Wetlands

The potential that wetlands in the riverine flow-through subclass have to remove metals and toxic organic compounds is assessed by their ability to reduce water velocities and trap sediment containing toxic compounds, and characteristics that indicate potential for precipitation and uptake by plants. The index for sediment removal is used to simplify the model since it includes the variables that reduce water velocity in a wetland. The sorptive properties of soils (adsorption processes) were judged not to be an important factor in this subclass because riverine flow-through wetlands are regularly flooded. Organic soils and clays usually do not accumulate in this geomorphic setting in western Washington.

8.3.3 Model at a Glance

Riverine Flow-through — Removing Metals and Toxic Organics

Process	Variables	Measures or Indicators
Sedimentation	**Ssed**	Index for "Removing Sediments"
Precipitation	**Vph**	pH of interstitial water
Plant Uptake	**Vtotemergent**	% area of emergent vegetation in AU
	Index:	Ssed + Vph + Vtotemergent / Score from reference standard site

8.3.4 Description and Scaling of Variables

***S*$_{sed}$** – Index for the function "Removing Sediments."

Rationale: The index is used to model the removal of toxic compounds from incoming waters because many of them comes into a wetland already bound to particulate sediments (for a review see Adamus et al. 1991).

Indicators: No indicators are needed. The variable is a index for a function.

Scaling: The index scaled between 0 and 10, and this is re-normalized to a range of 0 - 1.

***V*$_{pH}$** – The pH of interstitial water.

Rationale: Many toxic metals are precipitated out of water when the pH is low. Although there are a few, such as lead, that precipitate out at high pH, the Assessment Team judged that a low pH was better for removing toxic metals overall. Furthermore, the high pHs needed to precipitate a few metals (>9) are rarely, if ever, encountered in the wetlands of western Washington.

Indicators: pH can be measured directly using pH tabs.

Scaling: Low pH (<= 4.5) in the interstitial waters of an AU results in the highest score [1] and optimal removal. A pH between 4.5 and 5.5 scores a [0.5] and a pH > 5.5 scores a [0].

***V*$_{totemergent}$** – The areal extent (as % of AU) of emergent plant species in both the emergent zone and as an herbaceous understory to areas of forest and scrub/shrub.

Rationale: Emergent species have, in general, been found to sequester metals and remove oils and other organics better than other plant species (Hammer 1989; Horner 1992). AUs dominated by emergents were judged to sequester toxic metals and remove organic compounds better than those dominated by forest or scrub/shrub. Furthermore, the emergent vegetation and herbaceous understory support a higher microbial population that can decompose organic toxicants. This is due to a larger surface area exposed to incoming water.

Indicators: No indicators are needed. The areal extent (as % of AU) of emergent species and herbaceous understory is estimated directly.

Scaling: The scaling of the variable is based on the percent of the AU covered by emergent species (using the Cowardin definition) and by an herbaceous understory. AUs with a 100% cover of emergents + understory are scaled as [1]. AU's with a cover of less than 100% are scaled proportionally as %area/100.

8.3.5 Calculation of Potential Performance

Riverine Flow-through – Removing Metals and Toxic Organics

Variable	Description of Scaling		Score for Variable	Result
Ssed	*Score is scaled*	Index for Removing Sediment Function	Index of Function /10	
Vph	*Highest:*	pH less than of equal to 4.5	If D26.1 < = 4.5, enter "1"	
	Moderate:	pH between 4.5 and 5.5	If D26.1 > 4.5 and < = 5.5, enter "0.5"	
	Lowest:	pH greater than 5.5	If D26.1 > 5.5, enter "0"	
Vtotemergent	*Highest:*	100% of AU has herbaceous understory and/or emergents	If calculation = 1, enter "1"	
	Lowest:	AU has 0% emergent vegetation	If D14.5 + D16 = 0, enter "0"	
	Calculation:	Scaling = (% of AU with emergents + understory/100)	Enter result of calculation	
	Calculate [D14.5 + ((D16/100) x (D14.1+D14.2 + D14.3+ D14.4))] x 0.01			
			Total of Variable Scores:	
Index for Removing Metals and Toxic Organics = Total x 4 rounded to nearest 1				
			FINAL RESULT:	

8.3.6 Qualitative Rating of Opportunity

The opportunity of AUs in the riverine flow-through subclass to remove metals and toxic organic compounds should be judged using the characteristics of the upgradient watershed. Those land uses or activities that contribute metals and toxic organics to surface waters include urban areas and agricultural activities involving pesticide/herbicide applications.

Relatively undisturbed watersheds in the lowlands in western Washington will carry much lower loads of toxic chemicals than those that have been impacted by development or agriculture (Reinelt and Horner 1995). The opportunity that an AU has to remove toxic compounds is, therefore, linked to the amount of development and agriculture present in the upgradient part of its contributing basin

Users must make a qualitative judgement of the opportunity the AU actually has to remove toxic compounds by considering the land uses in the contributing watershed. The opportunity for an AU in the riverine flow-through subclass to remove toxic compounds is "**Low"** if most of its contributing watershed is undeveloped, and not farmed.

The opportunity for the AU to remove nutrients is **"High"** if the contributing watershed is mostly agricultural, urban, commercial, or residential.

The opportunity is **"Moderate"** if the activities that generate toxic compounds are a small part of the contributing watershed, or if they are relative far away from the AU.

The must use their judgement in deciding whether the opportunity is moderate or high, and document their decision on the data sheet.

8.4 Potential for Reducing Peak Flows — Riverine Flow-Through Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

8.4.1 Definition and Description of Function

Reducing Peak Flows is defined as the wetland processes or characteristics by which the peak flow in the downgradient part of the watershed is reduced during major rainfall events that cause flooding.
Surface water that may otherwise cause flooding is stored to a greater degree in a wetland than typically occurs in terrestrial environments. Wetlands reduce peak flows on streams and rivers by slowing and storing stream flow in overbank areas, and by holding back runoff during high water periods when it would otherwise flow directly downgradient and increase flooding.

Reduction in peak flows is often called water storage in other assessment methods (e.g. Brinson et al. 1995). The Assessment Team, however, decided to model more than just water storage. One of the major hydrologic functions of wetlands in watersheds of western Washington is to attenuate the severity of peak flows during flood events. The level of reduction in flow provided by an AU is a result of both the storage present within it and the amount of surface water entering the AU. AUs that have the same amount of storage may not reduce peak flows by the same amount if one has 10 times the volume of water entering it than the other during a flood event.

8.4.2 Assessing this Function for Riverine Flow-through Wetlands

The potential of riverine flow-through AUs to reduce peak flows is modeled based on the short-term storage capabilities and an estimate of the relative amount of water it can store during a flood event. Short-term storage in the riverine flow-through AUs is the relative amount of water it can store in the overbank areas. By definition wetlands in this subclass do not retain floodwaters much beyond the flood event and therefore are not ponded or constricted. Their storage is modeled as the width of the AU relative to the width of the stream. It is assumed that units that are wide relative to the stream will store more water than those that are narrow. Outlet characteristics will not play as important a role as in riverine impounding or depressional outflow wetlands.
The ratio of the area of the AU to the area of its contributing basin is used to estimate the relative amount of water it can hold during a flood event. Attempts were made during the field calibration to estimate relative flows using estimated runoff flows from rainfall data and USGS runoff data. Unfortunately, these data did not provide enough resolution between wetlands, and the ratio proved to be a more reliable variable. Another variable for flow that was considered was the stream order. Again the information available on stream order was not easily accessible nor was it very accurate.

8.4.3 Model at a Glance

Riverine Flow-through — Reducing Peak Flows

Process	Variables	Measures or Indicators
Short term storage	**Vau/stream**	Ratio of width of AU to width of stream
Amount of surface flow captured	**Vau/shed**	Ratio of area of AU to contributing basin
	Index:	$\dfrac{\text{Vau/stream} + (2 \times \text{Vau/shed})}{\text{Score from reference standard site}}$

8.4.4 Description and Scaling of Variables

$V_{au/stream}$ – The ratio of the width of the AU to the width of the stream, channel, or river within its boundaries or adjacent to it.

Rationale: The ratio is an indicator of the relative volume of storage available. The width of the stream between banks is a good indicator of the relative flows at that point in the watershed. Wider streams will have more flows than narrower streams. The width of the AU is used as an indicator of the amount of short-term storage available during a flood event. Wider units will have relatively more storage than narrower units. The ratio of the two values provides an estimate that make it possible to rank the units relative to each other in terms of their overall storage potential.

Indicators: No indicators are needed. The relative width of the AU and stream can be determined directly in the field.

Scaling: AUs whose width is greater than or equal to 20 times the width of the stream are scored a [1]. The rest are scored on a proportional scale relative to 20 (e.g. a ratio of 10 would score a 0.5 for the variable). If the AU has no stream , channel, or river within its boundaries or adjacent to it, it would score a [0].

$V_{au/shed}$ – The ratio of the area of the AU to the area of its contributing basin. **This variable was judged to be more important than the other in the equation and was given a weighting factor of 2.**

Rationale: The potential of an AU to reduce peak flows from its contributing basin is a function of its retention time (volume coming into a unit during a storm event /the amount of storage present). The area of the contributing basin is used to estimate the relative amount of water entering it, while the area of the AU is used to estimate the amount of storage present. Large contributing basins are expected to have larger volumes for any given storm event than smaller basins. In riverine flow-through AUs the entire unit is flooded by definition, and the total area is used as a surrogate for the amount of storage present.

Indicators: No indicators are needed. The ratio can be estimated from map measurements.

Scaling: AUs whose area is more than 1% (1/100) of the contributing basin are scored a [2]. Units whose ratio is smaller are scaled as based on the absolute value of the logarithm (base 10) of the ratio. It was necessary to transform the ratio to a logarithm to encompass the range of variability in the data from the reference units. The 2x multiplier is a scaling factor reflecting the importance of the variable. The Assessment Teams judged that this variable is more important than $V_{au/stream}$ in the performance of the function.

8.4.5 Calculations of Potential Performance

Riverine Flow-through – Reducing Peak Flows

Variable	Description of Scaling		Score for Variable	Result
Vau/stream	*Highest:*	Ratio of width of AU to width of stream > = 20	If calculation > = 20, enter "1"	
	Lowest:	No channel or stream in AU	If D4 = 0, enter "0"	
	Calculation:	Scaling is set as ratio/20	Enter result of calculation	
	Calculate (D6/D5)/20 to get result			
Vau/shed	*Highest:*	Ratio of area of AU to area of contributing basin is > = 0.01	If D1/D2 > = 0.01, enter "2"	
	Lowest:	Ratio of area of AU to area of contributing basin is < 10^{-10}	If D1/D2 < $10^{-10,}$, enter "0"	
	Calculation:	Scaling is based on the absolute value of the log of the ratio	Enter result of calculation	
	Calculate 2 x (2/ABS[log D1/D2]) to get result			
			Total of Variable Scores:	
Index for Reducing Peak Flows = Total x 3.33 rounded to nearest 1				
			FINAL RESULT:	

8.4.6 Qualitative Rating of Opportunity

The opportunity for an AU to reduce peak flows will increase as the water regime in the upgradient watershed is destabilized. Research in western Washington has shown that peak flows increase as the percentage of impermeable surface increase (Reinelt and Horner 1995). The opportunity should therefore be judged by the amount of upgradient watershed that is developed.

Users must make a qualitative judgement on the opportunity of the AU to actually reduce peak flows by considering the land uses in the contributing watershed. The opportunity for an AU in the depressional outflow subclass is **“Low”** if most of its contributing watershed is undeveloped, not farmed, or not recently logged. The opportunity is also **“Low”** if the AU receives most of its water from groundwater, rather than from an incoming stream, ditches, or storm drains).

The opportunity for the AU is **“High”** if the contributing watershed is mostly urban or high density residential. The opportunity is **“Moderate”** if the development is a small part of the contributing watershed, if the upgradient watershed is mostly agricultural, or if these areas are relative far away from the AU. Clear cut logging can also increase peak flows if a significant part of the watershed has recently been cut. These areas, however, will re-vegetate and within 5-7 years the peak flows may again be close to those found before logging. Too many variables are involved in trying to assess the increase in peak flows from logging (e.g. road density, time of cutting, % of watershed cut, etc.) and the rating for opportunity is too difficult to describe in a rapid method. Users must use their judgement to decide whether the opportunity is low, moderate or high, and document their decision on the summary sheet (Part 2).

8.5 Potential for Decreasing Downstream Erosion — Riverine Flow-through Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

8.5.1 Definition and Description of Function

Decreasing Downstream Erosion is defined as the wetland processes that decrease erosion of stream channels further downstream in the watershed by reducing the duration of erosive flows.

An AU performs this function if it stores excess runoff during and after storm events, before slowly releasing it to downgradient waters. This is similar to the function provided by stormwater retention/detention (R/D) ponds that are designed to prevent downstream erosion in developed areas. The AU decreases downstream erosion by reducing the duration of erosive flows (erosive flows are the high velocity, high volume flows that cause much of the erosion in a watershed).

The major processes by which wetlands reduce the duration of erosive flows is by storing some of the peak flows and thus reducing the time during which erosive flows occur, and by reducing the velocity of water flowing through the AU during a storm event. Erosive flows in a watershed occur above a certain velocity based on geomorphology. By reducing the velocity in general, an AU can reduce the overall time during which the erosive velocities occur.

The function of decreasing downstream erosion is closely related to that of reducing peak flows because a reduction in peak flows will also result in a reduction of velocity. All of the variables used in the “peak flow” model are used for this function as well. One way to consider the function being assessed is to ask, “What would happen to erosive flows in the watershed if the AU were filled?”.

8.5.2 Assessing this Function for Riverine Flow-through Wetlands

The potential of riverine flow-through wetlands is modeled in part by using the score for the function “Reducing Peak Flows.” The model for the function assesses the available storage during a storm event and the relative proportion of the flood that can be stored in the AU. Velocity reduction is then modeled by the amount of woody vegetation present.

The Assessment Team also judged that riverine flow-through wetlands contained within dikes have a lower potential to decrease downstream erosion. The dikes increase the velocity of water during a flood event by constraining the flow and raising the hydraulic head across the width of the flood channel.

8.5.3 Model at a Glance
Riverine Flow-through — Decreasing Downstream Erosion

Process	Variables	Measures or Indicators
Velocity reduction	**Vwoodyveg**	% of AU in forest and shrubs
Velocity reduction	**Sredpkflow**	Score for function "Reducing Peak Flows"
Reducers		
Dikes	**Vdikes**	Channel or stream contained within dikes
	Index:	(Vwoodyveg + Sredpkflow) **x Vdikes** / Score from reference standard site

8.5.4 Description and Scaling of Variables

$V_{woodyveg}$ – The % if the AU in woody vegetation.

Rationale: Surface water flowing through areas of stiff erect vegetation will have its velocity reduced because the vegetation provides a structural barrier to flow (see review in Adamus et al. 1991).

Indicators: The indicator for stiff erect vegetation is the % area within the AU of two Cowardin vegetation classes – forest and scrub/shrub. The Assessment Teams judged that these two classes represent vegetation that will remain erect during a flood event and will provide the structural barrier needed to reduce velocities.

Scaling: AUs that are 100% forest or scrub/shrub are scored a [1] for this variable. Scaling for the others is proportional, based on the % area that is covered by forest and/or scrub/shrub (%area / 100).

$S_{redpkflow}$ – The index for the function Reducing Peak Flows.

Rationale: The index for the function is used to simplify the model. The model for the function assesses the available storage during a storm event and the relative proportion of the flood that can be stored in the AU. The storage provided by the wetland reduces the maximum velocities downstream because peak flows are reduced.

Indicators: No indicators are needed. The variable is a index for another function.

Scaling: The index is already scaled between 0 and 10 and it is re-normalized to a range of 0 - 1.

V_{dikes} – The AU is within the boundaries of dikes that constrain flooding. **The presence of dikes is judged to reduce the potential of riverine flow-through wetlands to decrease erosion.**

Rationale: Dikes are judged to increase the velocity of water during a flood event by constraining the flow and raising the hydraulic head. The presence of dikes is also indicative of the fact that the full storage capacity of the floodplain has been reduced.

Indicators: No indicators are needed. The presence of dikes can be determined directly.

Scaling: This is an "on/off" variable. AUs within the boundaries of dikes that are within a distance of four channel widths of the channel are considered to be constrained by dikes. Such AUs have their sum of the other variables reduced by a factor of 0.5.

8.5.5 Calculation of Potential Performance

Riverine Flow-through – Decreasing Downstream Erosion

Variable	Description of Scaling		Score for Variable	Result
Vwoodyveg	*Highest:*	100% cover of shrub or forest	If calculation = 100, enter "1"	
	Lowest:	No cover of forest or shrubs	If calculation = 0, enter "0"	
	Calculation:	Scaling is set as % cover of SS + FO)/100	Enter result of calculation	
	Calculate (D14.1 + D14.2 + D14.3 + D14.4) / 100			
Sredpkflow	*Scaled score:*	Score for Reducing Peak Flows	Index of Function /10	
			Total of Variable Scores:	
Reducer				
Vdikes	Channel or stream contained within dikes		If D4.2 = 1, enter "0.5"	
	No dikes present		IF D4.2 = 0, enter "1"	
			Score for Reducer:	
Index for Decreasing Downstream Erosion = Total for variables x reducer x 5.26 rounded to nearest 1				
			FINAL RESULT:	

8.5.6 Qualitative Rating of Opportunity

The opportunity for an AU to decrease erosion will increase as the water regime in the upgradient watershed is destabilized. Research at the University of Washington has shown that peak flows and velocities increase as the percentage of impermeable surface increase (Reinelt and Horner 1995). The opportunity should therefore be judged by the amount of upgradient watershed that is developed.
Users must make a qualitative judgement on the opportunity of the AU to actually reduce peak flows by considering the land uses in the contributing watershed. The opportunity for an AU in the riverine flow-through subclass is **“Low”** if most of its contributing watershed is undeveloped, not farmed, or not recently logged. The opportunity for the AU is **“High”** is the contributing watershed is mostly urban or high density residential. The opportunity to is **“Moderate”** if the development is a small part of the contributing watershed, or if these areas are relative far away from the AU. Users must use their judgement in deciding whether the opportunity is low, moderate or high, and record their judgement on the summary sheet.

8.6 Potential for Recharging Groundwater — Riverine Flow-through Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

8.6.1 Definition and Description of Function

Recharging Groundwater is defined as the wetland processes by which surface water coming into a wetland is transported into subsurface water that flows either into unconfined aquifers or interflow that supports flows in streams during the dry season.

Riverine flow-through wetlands recharge groundwater by providing an area of infiltration during a flood event. Wetlands in this subclass do not recharge groundwater by storing water. Flow-through wetlands, by definition, are found in areas that are frequently flooded. Thus, they are usually found in the geomorphic setting that is called the "active channel."

The major aspect of recharge in riverine flow-through systems is infiltration water into groundwater that is closely linked to the stream or river itself. This hydrologic zone of shallow groundwater is called the hyporheic zone. The hyporheic zone has only recently come to be recognized as a critical component of the water regime and ecosystem of streams and rivers (Valett et al. 1993).

8.6.2 Assessing this Function for Riverine Flow-through Wetlands

The potential for wetlands in the riverine flow-through subclass to recharge the hyporheic zone is modeled as the relative rate of infiltration. Two variables are used; the first is a qualitative rating of the infiltration rate of the soils within the unit; and the second is the area over which the infiltration can occur relative to the size of the stream or river.

8.6.3 Model at a Glance

Riverine Flow-through — Recharging Groundwater

Process	Variables	Measures or Indicators
Infiltration	**Vinfilt**	Rating infiltration rate of soils
Infiltration	**Vau/stream**	Measured ratio of width of AU and width of stream
	Index:	Vinfilt + Vau/stream / Score from reference standard site

8.6.4 Description and Scaling of Variables

***V**$_{infilt}$* – A qualitative rating of the infiltration rate of soils in the AU.

Rationale: Infiltration can occur only where the soils are permeable. Recharge is an important process only if the soils have a high sand, gravel or cobble content, and a low content of clays, silts, or organic matter.

Indicators: The indicator of permeability is the relative amount of sand, silt, gravel, clay or organic matter present in the surface soils. Permeability of soils is rated down to a depth of 60 cm (2 ft).

Scaling: Soils with more than 50% of gravel and cobbles and less than 30% of clay or organic matter are scaled a [1] since these have the highest infiltration rate. Soils with more than 50% sand and less than 30% of clay or organic matter are scaled a [0.5]. Soils with more than 30% clays or organic matter are scaled a [0.1] because these have little or no infiltration.

$V_{au/stream}$ – The ratio of the width of the AU to the width of the stream, channel, or river within its boundaries or adjacent to it.

Rationale: The ratio is an indicator of the relative contribution the AU can provide to recharge of the hyporheic zone. The width of the stream between banks is a good indicator of the relative flood flows at that point in the watershed. Wider streams will have higher volume flood flows than narrower streams. The width of the AU is used as an indicator of the area through which recharge than can occur. Wider units will have relatively more recharge than narrower units for any given flow. The ratio of the two values provides an estimate that make it possible to rank the units relative to each other in terms of their overall potential to recharge the hyporheic zone.

Indicators: No indicators are needed. The relative width of the AU and stream can be determined directly in the field.

Scaling: AUs whose width is greater than or equal to 20 times the width of the stream are scored a [1]. The rest are scored on a proportional scale relative to 20 (e.g. a ratio of 10 would score a 0.5 for the variable). If the AU has no stream within its boundaries, or adjacent to it, it would score a [0].

8.6.5 Calculation of Potential Performance

Riverine Flow-through – Recharging Groundwater

Variable	Description of Scaling		Score for Variable	Result
Vinfilt	*Highest:*	Gravel, cobble >50% of soil and silt, clays, and organics < 30%	D48.1 = 1, enter "1"	
	Moderate:	Sand >50% of soil and silt, clays, and organics < 30%	D48.2 = 1, enter "0.5"	
	Lowest:	Silt, clay, and organics > 30% of soil	D48.3 = 1, enter "0.1"	
Vau/stream	*Highest:*	Ratio of width of AU/stream > = 20	If calculation > = 1, enter "1"	
	Lowest:	There is no stream in or adjacent to the AU	If D5 = 0, enter "0"	
	Calculation:	Scaling = ratio /20	Enter result of calculation	
	Calculate (D6/D5)/20 to get result			
			Total of Variable Scores:	
Index for Recharging Groundwater = Total x 6.66 rounded to nearest 1				
			FINAL RESULT:	

8.6.6 Qualitative Rating of Opportunity

Groundwater is an integral component of the water cycle throughout western Washington. The Assessment Teams have judged that all wetlands in the lowlands of western Washington have a **"High"** opportunity to recharge either interflow or an unconfined aquifer if the soils within the wetland are permeable enough. The assumption is that all wetlands have some link to groundwater.

8.7 General Habitat Suitability — Riverine Flow-through Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

8.7.1 Definition and Description of Function

General Habitat Suitability is defined as the characteristics or processes present in a wetland that indicate a general habitat suitability for a broad range of wetland-associated species. It also includes processes or characteristics within a wetland that help maintain ecosystem resilience (characteristics that are important in maintaining the ecosystem when it is disturbed). The assessment model attempts to assess how well an AU provides habitat for fauna. The model is not focused on individual species groups, but rather it emphasizes the elements in an AU that help support a range of different animal species. Plant species are addressed in a separate function. The "General Habitat Suitability" function may be used as a surrogate for "General Wildlife Habitat," though it is not restricted to the common definition of "wildlife" as mammals and birds. The general habitat function incorporates elements that are important to invertebrates and decomposers as well amphibians.

Many of the variables used to assess the performance of an AU for general habitat are also used in the assessments of habitat suitability for individual species groups. The SWTC and Assessment Teams, however, thought it important to assess General Habitat Suitability in broad terms as well as the individual species groups.

8.7.2 Assessing this Function for Riverine Flow-through Wetlands

An AU in the riverine flow-through subclass provides suitable habitat if it has a complex physical structure, high plant species richness, and seasonal or year-round standing water. The suitability of an AU also increases if it has high interspersion of "habitat" types within the AU.

The model is additive so that physical structures in the wetland (i.e. channels, upland/wetland edge, etc.) and biologic characteristics such as plant associations add to the general habitat suitability of an AU. The operative assumption is that the suitability of an AU for all species groups increases as the number of characteristics in the AU increase.

The presence of urban or high-density residential areas around an AU is included as a variable to reflect the potential for a reduction in the performance of this function. Development in the area around a wetland can result in increased surface water velocities, surface water volumes, pollution loadings, and changes in the water regime that have an impact on the suitability of a wetland as habitat (Reinelt and Horner 1995).

8.7.3 Model at a Glance

Riverine Flow-through — General Habitat Suitability

Characteristics	Variables	Measures or Indicators
Structural heterogeneity (applies to all variables)	**Vbuffcond**	Descriptive table of conditions in buffer
	V%closure	% area of canopy closure over AU
	Vstrata	Maximum number of strata in any one association
	Vsnags	Categories of snags present

	Vvegintersp	Interspersion between vegetation classes -diagrams
	Vlwd	Categories of LWD present
	Vhydrop	Number of water regimes present
	Vwintersp	Characteristics of water interspersion - diagrams
	Vprichness	Number of plant species present
	Vmature	Presence/absence of mature trees
	Vedgestruc	Structural complexity of AU edge
Reducers		
Surrounding land uses	**Vupcover**	Land uses within 1 km of AU
	Index:	(Vbuffcond + V%closure + Vstrata + Vsnags + Vvegintersp + Vlwd + Vhydrop + Vwintersp + Vprichness + Vmature + Vedgestruc) **x Vupcover** / Score for reference standard site

8.7.4 Description and Scaling of Variables

***V**$_{buffcond}$* – Condition of buffer within 100 m of the edge of the AU, as rated by extent of undisturbed areas.

Rationale: The condition of the buffer affects the ability of the AU to provide appropriate habitat for some species groups (Zeigler 1992). Terrestrial species using the wetland, that are dependent upon upland habitats for a portion of their life-cycles, benefit from the presence of relatively undisturbed upland community types immediately surrounding the wetland. Some guilds do not require upland habitats for a portion of their life-cycle. However, the presence of humans and domestic animals in close proximity to the wetland may impact some species that cannot escape to other refuge habitats.

Indicators: This variable is assessed using the buffer categorization described in Part 2.

Scaling: AUs with buffers are have relatively undisturbed for at least 100 m around 95% of the AU (buffer category #5) are scaled a [1]. The categories between 0-5 are scaled proportionally as 0, 0.2,0.4, 0.6, and 0.8.

***V**$_{\%closure}$* – The % canopy closure of woody vegetation higher than 1 m over the entire AU.

Rationale: The Assessment Teams judged canopy closure to be an important general habitat feature because it:

1) influences the micro-climate within the AU;
2) is a source of organic material in the duff layer;
3) stabilizes the soils within the AU; and
4) provides structural complexity for perches, nest sites, and invertebrates.

All of these factors contribute to increasing faunal richness.

Indicators: No indicators are needed to assess this variable. Canopy cover can be estimated directly.

Scaling: Generally, a canopy provides the best habitat conditions when the closure is moderate. The data from the reference sites suggests that a canopy closure between 30 and 60% is best [scaled as a (1)]. Either more or less canopy cover is not as good. Canopy closures between 10-29% and 61-100% were scored a [0.5], and canopy closures lower than these were scored a [0].

***V**$_{strata}$* - The maximum number of strata in any single plant association. A plant association (see Part 2 for operational definition of a plant association) can have up to 6 strata (layers: trees, shrub, low shrub, vine, herbaceous, mosses, and bryophytes). To count as a stratum, however, the plants of that stratum must have 20% cover in the association in which they are found.

Rationale: A greater number of strata provide more niches for different species than fewer strata. Strata are important to wildlife because different species utilize different strata for feeding, cover, and reproduction. Some species use a single strata exclusively throughout their life history (many invertebrates, for example, and some small mammal species) (Andrewartha and Birch 1984). Other species, on the other hand, require several strata to meet their life requirements. Consequently, an increase in number of strata will increase the suitability of an AU by increasing the potential species richness.
Indicators: No indicators are needed to assess this variable. The number of strata can be estimated directly.
Scaling: AUs with 5 or 6 strata are scored a [1] for this variable. AUs with only one are scored a [0]. AUs with 2, 3, 4 strata are scaled proportionally as 0.25, 0.5, and 0.75 respectively.

V_{snags} – The number of different snag categories based on state of decomposition states, found in the AU.

Rationale: Snags are the source of cavities in standing woody vegetation that provides habitat for numerous bird and mammal species. Many species of birds and mammals utilize cavities for nesting, roosting, denning, and/or refuge. Snag are invaded by invertebrates and other organisms of decay, which in turn provide food for many species of wildlife (Davis et. al. 1983). In addition, when snags fall, they contribute to the overall health of an ecosystem by decaying, which contributes nutrients to the soil (Maser et al. 1988). Furthermore, the presence of large snags was judged to be more important as a habitat feature than small snags because they have the potential for larger cavities as well as small ones; thus providing an additional niche in the wetland.

Indicators: The number and size of cavities within snags in an AU cannot be measured directly because they can be difficult to see during a "rapid" site visit. Snag characteristics and decay classes can be an estimate of the number, size and use of cavities. Eight different categories of snags representing different levels of decay are used as the indicator for the different potential sizes of cavities that may be found in the AU. It is assumed that snags will be used and cavities formed or excavated if dead branches or trunks are present. In addition, more importance is given if at least one of the snag categories is larger than 30 cm dbh.

Scaling: A riverine flow-through AU with 6 or more of the 8 categories of snag characteristics are present is scored a [1]. Fewer categories are scaled as proportional to 6 (i.e. # of categories/6). If the AU has any snag that is larger than 30 cm dbh, the score for V_{snag} is increased by 0.3.

$V_{vegintersp}$ – The extent of interspersion between Cowardin vegetation classes.
Rationale: The extent of interspersion between vegetation classes is a structural element of the wetland plant community that reflects habitat complexity. This is a measure of interspersion between classes, not a measure of the number of classes present. Consequently, an AU with only two Cowardin vegetation class types present may have a higher degree of interspersion than an AU with 3 Cowardin vegetation classes present.
In general, more "edge" between different vegetation community types increases the habitat suitability for some wildlife taxa. For example, a higher interspersion of plant types (as characterized by Cowardin vegetation classes) is likely to support a higher diversity of macro-invertebrates (Chapman 1966, Dvorak and Best 1982, Lodge 1985).
Indicators: The amount of interspersion between vegetation classes is assessed using diagrams developed from those found in the Washington State Rating System (WDOE 1993).
Scaling: AUs with more interspersion between vegetation classes score higher than those with fewer. The model has four categories of interspersion (none, low, moderate, high) and these are used as the basis for developing a scaled score. A high level of interspersion is scored a 1, a moderate a 0.67, a low = 0.33, and none = 0.

V_{lwd} – The number of categories (size and decay level) of downed large woody debris in the AU. This consists of woody debris found floating or partially submerged in permanent open waters as well as that found in the vegetated parts of the AU.
Rationale: Woody debris provides a major habitat niche for decomposers and invertebrates. Is also provides refuge for some amphibians and other vertebrates, and contributes to the production of organic soils.

Downed woody material is an important structural element of the wildlife habitat for many species. In the water, it is important for both resident and anadromous fish as well as numerous amphibians. In upland areas of the AU it provides shelter for small mammals, birds, and amphibians (Thomas et al. 1978). The downed woody material is also an important structural element for invertebrate species, which in turn provide food for much of the AU trophic web (Maser et al. 1988).

Indicators: Direct measures of the quantity and quality of decaying woody debris is not feasible for a rapid assessment method. A descriptive matrix of different classes and decay levels is used as an indicator for the variable. The matrix is based on the assessment procedure developed for the Timber Fish and Wildlife watershed assessment methods (Schuett-Hames et al. 1994).

Scaling: AUs with 10 or more categories of large woody debris in permanent open water and in vegetated areas score a [1]. The rest are scored proportionally to 10 (# categories /10).

$\boldsymbol{V_{hydrop}}$ – The number of different hydroperiods, or water regimes, present in the AU.

Rationale: Many aquatic species have their life cycles keyed to different water regimes of permanent, seasonal, or saturated conditions. A number of different water regimes in an AU will, therefore, support more species than an AU with fewer water regimes.

Indicators: The variable is assessed using specific hydroperiod classes as descriptors. These are permanently flowing stream, intermittently flowing stream, occasionally flooded, and saturated but not flooded as described below.

Permanently Flowing Stream – The AU contains a stream, channel, or ditch with water flowing in it throughout the year.

Intermittently Flowing Stream – The AU contains a stream, channel, or ditch in which water flow is intermittent or seasonal.

Occasionally Flooded or Inundated – Surface water is present for <u>brief</u> periods during the growing season, but the water table usually lies below the soil surface for most of the season. Plants that grow in both uplands and wetlands are characteristic of the temporarily flooded regime.

Saturated – The substrate is saturated to the surface for extended periods during the growing season, **but surface water is seldom present**. The latter criterion separates saturated areas from inundated areas. In this case there will be no signs of inundation on plant stems or surface depressions.

Scaling: AUs with three or four hydroperiod classes are scored a [1]. Those with fewer are score proportionally (2 classes = 0.5, 1 = 0).

$\boldsymbol{V_{wintersp}}$ – The extent of interspersion between vegetated areas of the AU and permanent streams.

Rationale: The extent of water interspersed with vegetation is another structural element of the AU that can add habitat complexity. The complexity of the braided pattern of the interface between open water and erect vegetation is an indicator of more habitat niches being available.

High interspersion between vegetation and water is important because of the increased variety of vegetation types and cover conditions that can result from such interspersion (Adamus et al. 1991). Contact zones between open water and vegetation provide protection from wind, waves, and predators, and may provide natural territorial boundaries for wildlife (Golet and Larson 1974). The transition between water and vegetation also provide habitat elements for both open-water and more terrestrial species (Weller and Spatcher 1965, and Willard 1977).

Indicators: The interspersion in an AU is assessed using a series of diagrams that rates the interspersion as high, moderate, low, and none.

Scaling: AUs with high interspersion are score a [1]; those with moderate are scored [0.67]; those with low = [0.33], and those with no interspersion (i.e. no permanent open water) = [0]

$\boldsymbol{V_{prichness}}$ – The total number of plant species present.

Rationale: The number of plant species in an AU is an indicator of the potential number of habitats for insects, other invertebrates, and microfauna. Many insects and detritivores are associated with a specific plant species in a parasitic, commensal or symbiotic relationship. The total number of wildlife species in an AU is expected to increase as the number of plant species increases. Plant species include both native and non-natives because both provide food, cover, and other habitat requirements for invertebrates.

Indicators: The indicator of overall plant richness is the number of species that is found during the field visit.

Scaling: Riverine flow-through AUs with 40 or more plant species are scored a [1]. Those with less are scored proportionally to 40 (# species/40). The Assessment Team recognizes that there may be some discrepancy between the number of species that can be identified in the summer and the number that can be identified in the winter.

$\boldsymbol{V_{mature}}$ – The AU has, or does not have mature trees.

Rationale: Mature trees within an AU are used as an indicator of habitat richness that is not captured in other variables. Mature trees are an indication that the area within the AU has had time to develop a complex physical structure on its surface (e.g. large and small woody debris with different levels of decomposition, a range of vegetation in different growth stages from seedlings to senescent). These structural elements provide an increased number of niches for many organisms.

Indicators: This variable is characterized by measuring the dbh (diameter at breast height) of the five largest trees of each species. If the average diameter of the three largest of a given species exceed the diameters given in Part 2, the AU is considered to contain a stand of mature trees. See Part 2 for a more detailed description of how to assess this variable.

Scaling: This is an "on/off" variable. AUs with mature trees are scored a [1], those without are scored a [0].

$\boldsymbol{V_{edgestruc}}$ – The vertical structure and linear characteristics of the AU edge.

Rationale: The convolutions (e.g., length of edge in relation to area of AU) and differences in heights of vegetation classes along the edge of the AU are important habitat characteristics for many wildlife species. Additional habitat exists within vegetated lobes and scalloped edges of wetlands. Further, embayments and peninsulas provide "micro-habitats" for certain species that require hiding cover, or visual isolation (USDI 1978, Verner et al. 1986, and WDOE 1993).

For example, a simple AU may be a circular pond with a fringing emergent marsh composed of cattails, which adjoins immediately to a grazed pasture. The edge in this case is characterized as having low structural richness (lack of shrubs and trees), and no convolutions (as the edge is nearly circular, with no embayments or peninsulas). In contrast, a more complex AU may adjoin an area composed of trees and shrubs, adding to the structural richness, and may be irregular along its edge, with many twists and turns, resulting in enclosed bays of emergent vegetation and jutting peninsulas of forest or shrub.

Indicators: The edge structure of the AU is assessed by using a descriptive key that groups the edges and vertical structure along the edge into high, medium, low, and no structural diversity.

Scaling: AUs with a highly diverse edge are scored a [1]; moderate = 0.67, low = 0.33, and none = 0.

$\boldsymbol{V_{upcover}}$ – the types of land uses within 1 km of the estimated edge of the AU. **This variable is used to indicate potential reductions in the level of performance for the function.**

Rationale: It is assumed that development (land conversion) around an AU will alter the water regime of the AU by shortening the time between the event and the peak within the AU. This will increase rates of flows through the AU, increase peak flows, increase volumes of water, and decrease low-flow duration from storm-water runoff from converted land-forms in the AU contributing basin. Wetland invertebrates and plants are also known to decrease in richness and abundance with greater water level fluctuations and concomitant pollution loads (Ludwa 1994, Schueler 1994, Azous and Richter 1995, and Hicks 1995)

Indicators: The indicator for this variable is the % of the land within a 1 km radius of the AU that is in urban, residential, or clear cut.

Scaling: The index of general habitat suitability is reduced by 10% (factor of 0.9) if the land uses within 1 km total more than 60% high density residential, low density residential, urban/commercial or clear cut.

8.7.5 Calculation of Habitat Suitability

Riverine Flow-through – General Habitat Suitability

Variable	Description of Scaling		Score for Variable	Result
Vbuffcond	*Highest:*	Buffer category of 5	If D42 = 5, enter "1"	
	High:	Buffer category of 4	If D42 = 4, enter "0.8"	
	Moderate:	Buffer category of 3	If D42 = 3, enter "0.6"	
	Medium Low:	Buffer category of 2	If D42 = 2, enter "0.4"	
	Low:	Buffer category of 1	If D42 = 1, enter "0.2"	
	Lowest:	Buffer category of 0	If D42 = 0, enter "0"	
V%closure	*Highest:*	Canopy closure between 30-60%	If D17 > = 30 and D17 < = 60, enter "1"	
	Moderate:	Canopy closure between 10-29% or 61-100%	If D17 = 10-29 or D17 > 60, enter "0.5"	
	Lowest:	Canopy closure <10 %	If D17 <10, enter "0"	
Vstrata	*Highest:*	5 or 6 strata present	If D21 > = 5, enter "1"	
	High:	4 strata present	If D21 = 4, enter "0.75"	
	Moderate:	3 strata present	If D21 = 3, enter "0.5"	
	Medium low:	2 strata present	If D21 = 2, enter "0.25"	
	Low:	1 stratum present	If D21 = 1, enter "0"	
Vsnags	*Highest:*	AU has at least 6 categories of snags and some have > 30 cm dbh	If D31 > = 6 and D31.1 =1, enter "1.3"	
	Lowest:	No snags present	If D31 = 0, enter "0"	
	Calculation:	Scaled as number of categories divided by 6 + 0.3 if dbh is > 30 cm	Enter result of calculation	
	If D31 < 6 calculate D31/6 + (D31.1 x 0.3) to get result			
Vvegintersp	*Highest:*	High interspersion	If D39 = 3, enter "1"	
	Moderate:	Moderate interspersion	If D39 = 2, enter "0.67"	
	Low:	Low interspersion	If D39 = 1, enter "0.33"	
	Lowest:	AU has no interspersion (1 class only)	If D39 = 0, enter "0"	
Vlwd	*Highest:*	AU has at least 10 size and decomposition categories of LWD	If calculation > = 1, enter "1"	
	Lowest:	No categories of LWD	If calculation = 0, enter "0"	
	Calculation:	Scaling based on the number of categories divided by 10	Enter result of calculation	
	Calculate (D44 + D45)/10 to get result			
Vhydrop	*Highest:*	AU has w or 4 water regimes present	If D9.3 + D9.4 + D9.5 + D9.6 > = 3, enter "1"	
	High:	AU has 2 water regimes present	If D9.3 + D9.4 + D9.5 + D9.6 = 2, enter "0.50"	
	Low:	AU has 1 water regime present	If D9.3 + D9.4 + D9.5 + D9.6 = 1, enter "0"	
Vwintersp	*Highest:*	High interspersion	If D38 = 3, enter "1"	
	Moderate:	Moderate interspersion	If D38 = 2, enter "0.67"	
	Low:	Low interspersion	If D38 = 1, enter "0.33"	
	Lowest:	No interspersion	If D38 = 0, enter "0"	

Table continued on next page

Variable	Description of Scaling		Score for Variable	Result
Vprichness	*Highest:*	Number of plant species > = 40	If calculation > = 1.0, enter “1”	
	Lowest:	AU has 2 or less plant species	If calculation < = 0.05, enter “0”	
	Calculation:	Scaled as # of species/40	Enter result of calculation	
	Calculate (D19.1 + D19.2)/40 to get result			
Vmature	*Highest:* *Lowest:*	AU has mature trees present AU has no mature trees present	If D22 = 1, enter “1” If D22 = 0, enter “0”	
Vedgestruc	*Highest:*	High structure at edge of AU	If D41 = 3, enter “1”	
	Moderate:	Moderate structure	If D41 = 2, enter “0.67”	
	Low:	Low structure	If D41 = 1, enter “0.33”	
	Lowest:	No structure	If D41 = 0, enter “0”	
			Total of Variable Scores:	
Reducer				
Vupcover	If clear cutting, high and low density residential, and urban land uses within 1 km are > = 60%		If D3.3 + D3.4 + D3.5 + D3.6 > = 60, enter “0.9”	
	If critical land uses < 60%		Enter 1	
			Score for Reducer:	
Index for General Habitat Suitability = Total for variables x reducer x 1.09 rounded to nearest 1				
			FINAL RESULT:	

8.7.6 Qualitative Rating of Opportunity

The land-use patterns within the upland buffer and surrounding landscape influences the opportunity that an AU has to provide general habitat. Connectivity of AUs to other protected areas affects species use of the habitat within the AU, in particular those species whose life history needs include a large range of landscape types (e.g. the larger predators, raptors, etc.). For some populations, the connectivity between wetland habitats may be crucial to the survivability of the population.

The opportunity that an AU has to provide habitat for a broad range of species should be judged by characterizing the landscape in which an AU is found. An AU may have many internal structural elements that indicate it provides good habitat. Its landscape position, however, may reduce the actual performance because it is not accessible to the populations that would use it.

Users must make a qualitative judgement on the opportunity the AU has in providing habitat for a broad range of species by considering the land uses in the contributing watershed, the condition of its buffer, and its connection to other habitat areas. Two data on the data sheets can be used to help guide your judgement (D43 on corridors and D42 on buffers).

In general, the opportunity for an AU in the riverine flow-through subclass to provide habitat is **“High”** if it has extensive natural buffers and forested or riparian corridors to other habitats. Other habitats may include undisturbed grasslands, open water, shrubs, or forested areas. The opportunity is **“Moderate”** if the AU has some connections to other habitat areas or less extensive undisturbed buffers. It is **“Low”** if the AU is surrounded by development and has no naturally vegetated corridors to other habitat areas.

The user must use their judgement in deciding whether the opportunity is low, moderate or high, and document their decision on the data sheet.

8.8 Habitat Suitability for Invertebrates — Riverine Flow-through Wetlands

> **Note**: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

8.8.1 Definition and Description of Function

Habitat Suitability for Invertebrates is defined as the wetland characteristics that help maintain a high number of invertebrate species in the wetland. The term invertebrates is here more narrowly defined as "macro-invertebrates" or free-living organisms readily seen with the naked eye (>200-500 um). They include: Insecta (insects), Amphipoda (scuds, sideswimmers), Eubranchiopoda (fairy, tadpole, and clam shrimps), Decapoda (crayfishes, shrimps), Gastropoda (snails, limpets), Pelecypoda (clams, mussels), Hydracarina (water mites), Arachnida (spiders), and Annelida (worms and leeches).

The intent of the assessment is to identify those wetlands that provide habitat for the greatest number of invertebrate species within the regional subclass. Invertebrates are diverse, abundant, and essential components of freshwater aquatic ecosystems. Almost any AU will provide a habitat for some invertebrates. There is a distinct difference, however, between an AU that has a high abundance of one or two species and one that has a high richness of many different species. The important aspect of invertebrate populations that is being assessed is species richness. Wetlands with a high richness tend to be more important in maintaining the regional biodiversity of invertebrate populations and by providing genetic diversity that helps maintain ecosystem integrity.

Invertebrates have evolved unique adaptations to enable them to occupy most wetland habitats and trophic levels. Consequently, wetland invertebrates are pivotal components of complex food webs, significantly increasing the number of links with the rich diversity and abundance of their taxa. As filter feeders, shredders and scrapers, insects convert and assimilate microorganisms and vegetation into biomass providing significant production that then becomes available to secondary and tertiary consumers. Recent research focusing on aquatic invertebrates in wetlands indicates the importance of macro-invertebrates in energy and nutrient transfer within aquatic ecosystems (Rosenberg and Danks 1987). They furnish food for other invertebrates and comprise significant portions of the nutritional requirements of amphibians, water birds and small mammals. They are an especially important food source for young fish (e.g., salmonids and game fish). The trophic diversity and numerical abundance of insects, and especially Diptera (true flies), make these organisms the most important taxa in wetland environments.

In addition, macro-invertebrates have been used as bioindicators of stream and lake (Rosenberg and Resh 1996) and increasingly of wetland health (Hicks 1996); their taxa and numbers indicating conditions of hydrodynamics, hydrology, soils, vegetation, eutrophication, and anthropogenic pollution.

8.8.2 Assessing this Function for Riverine flow-through Wetlands

The suitability of wetlands in the riverine flow-through subclass as habitat for a highly diverse assemblage of invertebrates is assessed by characterizing the complexity of the biologic, and physical structures of the AU. The model is built on the assumption that almost any structure in the AU (i.e. channels, ponds, upland/AU edge, etc.) or plant association hosts a specialized invertebrate community. The operative assumption is that the richness of invertebrate species increases as the number of structural characteristics in an AU increase. Tannins were not found in any reference site of the riverine flow-through subclass. The Assessment Teams judged that this factor is not an important reducer of habitat suitability in this subclass.

8.8.3 Model at a Glance

Riverine Flow-through — Habitat Suitability for Invertebrates

Characteristics	Variables	Measures or Indicators
Number of habitat niches for invertebrates (applies to all variables)	**Vpermflow**	Channels or streams in AU with permanently flowing water
	Vsubstrate	Types of surface substrates present
	Vwintersp	Characteristics of water interspersion - diagrams
	Vlwd	Categories of LWD present
	Vstrata	Number of strata present in any plant association
	Vvegintersp	Interspersion between vegetation classes -diagrams
	Vassemb	Number of plant assemblages
	Vaquastruc	Categories of different aquatic bed structures
	Index:	(Vpermflow + Vsubstrate + Vwintersp + Vlwd + Vstrata + Vvegintersp + Vassemb + Vaquastruc) / Score from reference standard site

8.8.4 Description and Scaling of Variables

$V_{permflow}$ – Channels or streams are present in an AU and contain permanent flowing water.

Rationale: Permanent flowing water is a habitat feature that supports a unique assemblage of invertebrate species (Needham and Needham 1962, and Wiggins et al. 1980). Invertebrates that are found in permanent flowing channels are an important resource for many other aquatic species (Needham and Needham 1962). The presence of a permanent flowing water is a characteristic whose presence adds to the overall invertebrate richness in an AU.

Streams or channels with intermittent seasonal flow also have the potential for providing a special invertebrate habitat. They are not scaled in the model, however, because it was not possible to determine, in the field, if an intermittent stream or channel is maintained by seasonal flows or by high rainfall events. If an intermittent stream is a result of storm flows, the water does not remain long enough to provide a unique invertebrate habitat.

Indicators: No indicators are needed for this variable because the presence of permanent flow in a channel can be established directly in the summer during the dry season. Indicators for the presence of permanent channel flow in the winter, during the wet season, may be more difficult to establish. Users may have to rely on aerial photographs (usually taken in the summer) or other sources of information to determine if the flows in a channel are permanent.

Scaling: This is an “on/off” variable. An AU scores a [1] if permanent channel flow is present, and a [0] if it is not.

$V_{substrate}$ – The composition of surface layers present in the AU (litter, mineral, organic etc).

Rationale: Not much is known about invertebrate distributions in different substrates within a wetland. Data from rivers, streams, and lakes, however, show that the local invertebrate species have preferences for specific substrate (Dougherty and Morgan 1991, and Gorman and Karr 1978). In streams it is well known that Chironomid community composition is strongly affected by sediment characteristics (McGarrigle 1980, and Minshall 1984). The Assessment Teams assumed that a similar relationship between invertebrate populations and substrates is also found in AUs. Thus, AUs with different substrates present will provide habitat for a broader group of invertebrates than those with only one type. Moreover, those with organic matter will exhibit greater richness and abundance than those found in sand substrates.

Indicators: No indicators are needed to assess this variable. The number of different substrate types can be determined by direct field observations.

Scaling: AUs with six or more types of substrates of the eight identified (deciduous leaf litter, other plant litter, decomposed organic, exposed cobbles, exposed gravel, exposed sand, exposed silt, exposed clay) are scored a [1]. Those with fewer are scaled proportionally (# types/6). AUs with no non-living surface exposed (e.g. sphagnum bog) are scored a [0].

$V_{wintersp}$ – The amount of interspersion present between vegetated portions of AU and permanent stream in or adjacent to the AU.

Rationale: The amount of interspersion between the stream and vegetation is another structural element of the AU that can add habitat complexity. Studies have shown that high invertebrate richness occurs in water interspersed with stands of emergent vegetation (Voigts 1976).

Indicators: The interspersion in an AU is assessed using a series of diagrams that rates the interspersion as high, moderate, low, and none.

Scaling: Riverine flow-through AUs with high interspersion score a [1]; those with moderate are scored [0.67]; those with low = [0.33]; and those with no interspersion (i.e. no permanent open water) = [0].

V_{lwd} – The number of categories, based on size and level of decay, of fallen large woody debris (LWD) in permanent open water and on the vegetated surface of the AU. The categories are based on the Timber, Fish, and Wildlife rating criteria (Schuett-Hames et al. 1994).

Rationale: Downed woody material is an important structural element for invertebrate species. Decaying wood provides an important habitat for invertebrates (Maser et al. 1988). The Assessment Teams assumed that downed debris of different size and different levels of decay classes would provide habitat for a wide variety of invertebrates, especially those that decompose, feed, and seek shelter in wood.

Indicators: Direct measures of the quantity and quality of decaying woody debris is not feasible for a rapid assessment method. Consequently, a descriptive matrix of different sizes and decay classes of woody debris was developed as an indicator for the variable. The matrix is based on the assessment procedure developed for the TFW watershed assessment methods.

Scaling: AUs with 10 (out of 24 possible) or more categories of LWD in open water and on the surface are scored a [1]. Those with less are scaled proportionally (# categories/10).

V_{strata} **–** The number of vegetation strata in any single plant assemblage. A plant assemblage can have up to 6 strata (layers: trees, high shrubs, low shrubs, woody vine, herbaceous, moss). To count as a stratum, however, the plants of that stratum have to have 20% cover in the association in which it is found.

Rationale: Different invertebrate taxa are found on different plant species (Cyr and Downing 1988). The vegetation strata are used as an indicator of distinct groups of plant species that might have specific ecological characteristics to which invertebrate taxa might be adapted.

Indicators: No indicators are needed for this variable. The number of strata present in any single plant assemblage can be determined by direct field observations.

Scaling: AUs with>= 5 strata are scored a [1] for this variable. AUs with only one are scored a [0]. AUs with 2-4 strata are scaled proportionally as 0.25, 0.5, and 0.75 respectively.

$V_{vegintersp}$ – The extent of interspersion between Cowardin vegetation classes.

Rationale: The extent of interspersion between vegetation class is a structural element of the plant community in an AU that reflects on habitat complexity. A higher diversity of plant communities (as characterized by Cowardin vegetation classes) is likely to support a higher diversity of macro-invertebrates (Chapman 1966, Dvorak and Best 1982, Lodge 1985).

Indicators: The extent of interspersion between vegetation classes is assessed using diagrams found in the Washington State Rating System (WDOE 1993).

Scaling: AUs with more interspersion between vegetation classes score higher than those with fewer. The method has four categories of interspersion (none, low, moderate, high) and these are used as the basis for developing the scaled score. A high level of interspersion is scored a 1, a moderate = 0.67, a low = 0.33, and none = 0.

V_{assemb} – The number of distinct plant assemblages found within the AU.

Rationale: A mixture of plant assemblages exhibits a greater diversity and biomass of invertebrates than does a single plant one within an area (Andrews and Hasler 1943). For example, the standing crop of invertebrates varies considerably among different species of submerged aquatic macrophytes (Murkin and Batt 1987), and different epiphytic invertebrate taxa are found on different plant species (Cyr and Downing 1988).

Indicators: No indicators are needed to assess this variable. The number of associations can be determined through field observations.

Scaling: Riverine flow-through AUs with 10 or more plant associations are scored a [1]. AUs with fewer are scaled proportionally [(# associations-1)/9].

$V_{aquatstruc}$ – The number of different types of plant structures present in aquatic bed vegetation of the stream, channel or river within the AU.

Rationale: Different types of aquatic bed vegetation provide structure and consequently different niches for invertebrates (Wilcox and Meeker 1992). Thus, species richness increases as the structural diversity of aquatic bed vegetation increases.

This variable was found to be important even in riverine flow-through wetlands because many low gradient flow-through wetlands in western Washington were found with aquatic bed vegetation during the calibration process.

Indicators: This variable is quantified using a diagram showing different types of structures found in aquatic bed vegetation.

Scaling: AUs with all three types of structure present score a [1]. Those with 2 score a [0.67]; those with 1 score [0.33]; and those with none score a [0].

8.8.5 Calculation of Habitat Suitability

Riverine Flow-through – Habitat Suitability for Invertebrates

Variable	Description of Scaling		Score for Variable	Result
Vpermflow	*Highest:*	AU has permanently flowing stream	If D4.1 = 1, enter "1"	
	Lowest:	AU has no permanent stream	If D4.1 = 0, enter "0"	
Vsubstrate	*Highest:*	6 categories of surface layers	If calculation > = 1.0, enter "1"	
	Lowest:	AU has no solid surface exposed	If calculation = 0, enter "0"	
	Calculation:	Scaling based on # of surface layer categories present/6	Enter result of calculation	
	Calculate sum (D46.1 - D46.8)]/6 to get result			
Vwintersp	*Highest:*	High interspersion	If D38 = 3, enter "1"	
	Moderate:	Moderate interspersion	If D38 = 2, enter "0.67"	
	Low:	Low interspersion	If D38 = 1, enter "0.33"	
	Lowest:	No interspersion	If D38 = 0, enter "0"	
Vlwd	*Highest:*	AU has at least 10 LWD size and decomposition categories	If calculation > = 1.0, enter "1"	
	Lowest:	No categories of LWD	If calculation = 0, enter "0"	
	Calculation:	Scaling based on # of categories/10	Enter result of calculation	
	Calculate (D44 + D45)/10 to get result			
Vstrata	*Highest:*	5 or 6 strata present	If D21 > = 5, enter "1"	
	High:	4 strata present	If D21 = 4, enter "0.75"	
	Moderate:	3 strata present	If D21 = 3, enter "0.5"	
	Medium low:	2 strata present	If D21 = 2, enter "0.25"	
	Low:	1 stratum present	If D21 = 1, enter "0"	
Vvegintersp	*Highest:*	High interspersion	If D39 = 3, enter "1"	
	Moderate:	Moderate interspersion	If D39 = 2, enter "0.67"	
	Low:	Low interspersion	If D39 = 1, enter "0.33"	
	Lowest:	No interspersion (1 class only)	If D39 = 0, enter "0"	
Vassemb	*Highest:*	AU has at least 10 plant assemblages	If calculation > = 1, enter "1"	
	Lowest:	AU has 1 plant assemblages	If D20 = 1, enter "0"	
	Calculation:	Scaling based on # of assemblages / 9	Enter result of calculation	
	Calculate (D20 – 1) / 9 to get result			
Vaquastruc	*Highest:*	3 aquatic bed vegetation structures	If D25 = 3, enter "1"	
	High:	2 aquatic bed vegetation structures	If D25 = 2, enter "0.67"	
	Moderate:	1 aquatic bed vegetation structure	If D25 = 1, enter "0.33"	
	Lowest:	0 aquatic bed vegetation structures	If D25 = 0, enter "0"	
			Total of Variable Scores:	
Index for Habitat Suitability for Invertebrates = Total for variables x 1.52 rounded to nearest 1				
			FINAL RESULT:	

8.9 Habitat Suitability for Amphibians — Riverine Flow-through Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

8.9.1 Definition and Description of Function

Habitat Suitability for Amphibians is defined as the wetland characteristics that contribute to the feeding, breeding, or refuge needs of amphibian species. Amphibians in the lowlands of western Washington are a vertebrate group that include wetland-breeding frogs and toads (e.g., Order Anura, tailless amphibians except as larvae) and salamanders and newts (e.g., Order Caudata (Uradela) tailed amphibians). Their richness and abundance indicates they are extremely important in wetland trophic organization. Many native species only breed for a short time in wetlands and live in uplands as metamorphosed juveniles and adults (Richter 1998). Some species may be found in or close to wetlands throughout the year. Eggs and larvae of species that breed in wetlands, however, require free water for development.

Wetlands play an important role in the life cycles of amphibians by providing the quiet waters, shelter, and food sources needed for the early stages of development. The suitability of a riverine flow-through AU as amphibian habitat is assessed by characterizing the conditions in a wetland provide protection and food for larvae and adults moving in and out of the wetland. Amphibians, however, do not generally breed in riverine flow-through wetlands because the water does not remain long enough to permit full egg development.

In general, the suitability of an AU as amphibian habitat increases as the number of the appropriate habitat characteristics increase for all life stages. **The assessment model is focused on species richness and conditions that would support many different species, not on the importance of a wetland to a specific threatened or endangered species.**

If the wetland is a habitat type that appears to be critical to a specific species, another method is needed in order to better determine the habitat suitability of that wetland.

8.9.2 Assessing this Function for Riverine Flow-through Wetlands

The suitability of an AU in the riverine flow-through subclass as habitat for amphibians is modeled on habitat characteristics that are important for the survival of amphibians in riverine wetlands without any seasonal ponding. Variables associated with the opportunity that an AU has to provide suitable habitat were not included, such as proximity to other aquatic resources. These variables represent landscape conditions that impact suitability, but do not reflect the structural components of the AU itself.

Two variables included (V_{phow} and $V_{upcover}$) that reflect the potential for a reduction in the performance of this function. Acidic waters will impair larval and adult development. Furthermore, natural habitats in the surrounding uplands are considered to be of paramount importance for maintaining viable amphibian populations (Semlitsch 1981, Kleeberger and Werner 1983, Bury and Corn 1988, and Dupuis et al. 1995). The absence of natural vegetation is modeled as a reduction in suitability of the wetland itself because it is a necessary condition if the wetland is to provide a suitable habitat for amphibians.

The Assessment Teams considered using the presence of fish and bullfrogs as a reducer of habitat suitability because both of these predators are known to prey on native amphibian larvae. However, the presence of these species cannot always be determined during a single site visit. Users of the method are encouraged, however, to record the presence of either fish or bullfrogs of their data sheet. If either predator is present, the index that is calculated by the assessment model may not reflect the actual habitat suitability of the AU.

8.9.3 Model at a Glance

Riverine Flow-through — Habitat Suitability for Amphibians

Process	Variables	Measures or Indicators
Breeding, feeding, refuge for amphibians (applies to all variables)	**Vbuffcond**	Descriptive table of conditions in buffer
	Vsubstrate	Types of surface substrates present
	Vpermflow	Permanently flowing stream
	Vpools	Micro-depressions in stream bed
	Vlwd	Categories of LWD present
Reducers		
	Vphow	pH tabs, direct measurement
	Vupcover	Land uses within 1 km of wetland
	Index:	(Vbuffcond + Vsubstrate + Vpermflow + Vpools + Vlwd) x (Vphow or Vupcover) / Score from reference standard site

8.9.4 Description and Scaling of Variables

$V_{buffcond}$ – Condition of buffer within 100 m of the edge of the AU, as rated by extent of undisturbed areas.

Rationale: Conditions in the buffers of an AU are especially important in providing cover to newly metamorphed animals. They are important to the tiger salamander (*A. tigrinum*) seeking shelter in rodent burrows during the first days following emigration from natal ponds (Loredo et al. 1996). Metamorphs of *P. regilla*, *B. boreas R. aurora* and *T. granulosa* may spend several weeks in buffers prior to dispersing upland if soil and vegetation is dry beyond the buffer (Richter pers. obs.). Vulnerable metamorphs and juveniles have moisture, cover, and abundant invertebrate prey within forested wetland buffers.

Indicators: This variable is determined using a buffer categorization developed from the Washington State Rating System (WDOE 1993) (see data sheets Part 2).

Scaling: Buffer categories are scaled as follows: category 5 = 1, category 4 = 0.8, category 3 = 0.6, category 2 = 0.4, category 1 = 0.2, category 0 = 0.

$V_{substrate}$ – The composition and types of surface layers present in the AU (litter, mineral, organic etc).

Rationale: Organic matter and leaf litter are important to amphibians as substrates for the zooplankton, phytoplankton, algae, and invertebrates that provide their food. Moreover, structural diversity in the form of leaf litter and woody debris provides shelter from weather and cover from predation. Different types of substrates provide niches for different invertebrate communities and thereby increase the richness of potential food sources.

Indicators: No indicators are needed to assess this variable. The substrate types can be determined by direct field observations.

Scaling: Scaling is based on the total number of different types of substrate present in the AU. Organic substrates, however, are given more importance (by a factor of two) because of their additional role as shelter. AUs with 3 categories of organic litter and 3 categories of inorganic surface types are scored a 1. Those with fewer are scaled proportionally (see Calculation Table 8.9.5).

$V_{permflow}$ – Channels or streams are present in AU and contain permanent flowing water.

Rationale: Permanent flowing water is a habitat feature that supports a unique assemblage of amphibians such as the Northwest salamander.

Indicators: No indicators are needed for this variable in the summer because the presence of flow in a channel can be established directly during the dry season. Indicators for the presence of permanent channel flow in the winter, during the wet season, may be more difficult to establish. Users may have to rely on aerial photographs (usually taken in the summer) or other sources of information to determine if the flows in a channel are permanent.

Scaling: This is an "on/off" variable. An AU scores a [1] if permanent channel flow is present, and a [0] if it is not.

V_{pools} – Stream in the AU has micro-depressions that form small pools after a flood event.

Rationale: Over the past 8 years, K. McAllister (WDFW) and W. Leonard from the Department of Ecology have monitored amphibians in wetlands along both Dempsey Creek and an unnamed, seasonal tributary to Dempsey Creek in Thurston County (both riverine flow-through wetlands). Long-toed Salamanders, Pacific Treefrogs, and Oregon Spotted Frogs tended to select shallow (5 to 30 cm), overflow pools within the creek bed or immediately adjacent to it for feeding and resting. These areas typically lack any significant flow.

Indicators: No indicators are needed for this variable in the summer because the presence of depressions in a channel can be established directly during the dry season. Indicators for the presence of pools in the winter, during the wet season, may be more difficult to establish. Users may have to rely on aerial photographs (usually taken in the summer) or other sources of information to determine if small pools are present.

Scaling: This is an "on/off" variable. An AU scores a [1] if pools are present, and a [0] if they are not.

V_{lwd} – The number of categories, based on size and level of decay, of fallen large woody debris (LWD) in the permanent open water and on the vegetated surface of the AU. The categories are based on the Timber, Fish, and Wildlife rating criteria (Schuett-Hames et al. 1994).

Rationale: There is no clear documentation of the quantity and type of large woody debris that is of benefit to amphibians in wetlands. However, tadpoles of western toads (*Bufo boreas*) frequently rest attached to large floating logs (Richter pers. obs.). Large woody debris in water most likely is important also as cover for larvae and adults, and as attachment sites for the algae and invertebrates that provide food.

Indicators: Direct measures of the quantity and quality of decaying woody debris is not feasible for a rapid assessment method. A descriptive matrix of different sizes and decay classes of woody debris was developed as an indicator for the variable. The matrix is based on the assessment procedure developed for the TFW watershed assessment methods.

Scaling: AUs with 10 (out of 24 possible) or more categories of LWD in open water and on the surface are scored a [1]. Those with less are scaled proportionally (# categories/10).

V_{phow} **–** The pH of open surface water in the AU. This variable is used to indicate potential reductions in the level of performance for the function.

Rationale: Acidic waters impair development of Pacific Northwest amphibians. Hence they are generally absent from wetlands with a pH in its surface waters of 4.5 or less (Richter unpub. data).

Indicators: No indicators are needed. The pH of surface water can be measured directly using pH strips.

Scaling: AUs with a pH of 4.5 or less are assigned an index of [0] for the function. Those with a pH >4.5 but < 5.5 have their index reduced by a factor of 0.5. AUs with a pH of 5.5 or greater do not have their index reduced.

$V_{upcover}$ – The types of land uses within 1 km of the estimated AU edge. This variable is used to indicate potential reductions in the level of performance for the function.

Rationale: Wetlands that provide full range of biological processes of consequence to amphibians are located in relatively undeveloped areas (Schueler 1994, and Richter and Azous 1995). Development increases water discharges, current velocities, and water level fluctuations in the AU. These environmental conditions diminish suitable amphibian breeding, feeding, and rearing habitat. Moreover, wetland invertebrates and plants are also known to decrease in richness and abundance with greater water level fluctuations and concomitant pollution loads (Schueler 1994, Ludwa 1994, Azous and Richter 1995, and Hicks 1995) further reducing the quality of amphibian habitat in the AU.

Indicators: No indicators are needed to assess this variable. The amount and type of land uses within 1 km of the wetland can be established from aerial photographs or site visits.

Scaling: AUs with at least 60% of their surrounding land in urban or high density residential use have their index for the function reduced by a factor of 0.5. Those with at least 50% in clear-cut are also reduced by 0.5. AUs with at least 30% of their surrounding areas in any active land use (residential, urban, clear-cut, or agriculture) have their index reduced by a factor of 0.8.

8.9.5 Calculation of Habitat Suitability

Riverine Flow-through – Habitat Suitability for Amphibians

Variable	Description of Scaling		Score for Variable	Result
Vbuffcond	*Highest:*	Buffer category of 5	If D42 = 5, enter "1"	
	High:	Buffer category of 4	If D42 = 4, enter "0.8"	
	Moderate:	Buffer category of 3	If D42 = 3, enter "0.6"	
	Medium low:	Buffer category of 2	If D42 = 2, enter "0.4"	
	Low:	Buffer category of 1	If D42 = 1, enter "0.2"	
	Lowest:	Buffer category of 0	If D42 = 0, enter "0"	
Vsubstrate	*Highest:*	3 categories of organic litter + 3 inorganic surface layers	If D46.1 + D46.2 + D46.3 = 3 and sum (D46.4 - D46.8) > =3, enter "1"	
	Lowest:	AU has no ground surface exposed	If sum (D46.1-D46.8) = 0, enter "0"	
	Calculation:	Scaling based on # of surface layer categ., organic layers weighted by factor of 2, normalized as # categ./9	Enter result of calculation	
	If sum (D46.4 - D46.8) > = 3 calculate [(D46.1 + D46.2 + D46.3) x 2 + 3]/9; if sum (D46.4 - D46.8) < = 21 calculate [(D46.1 + D46.2 + D46.3) x 2 + sum (D46.4 - D46.8)] / 9			
Vpermflow	*Highest:*	Permanently flowing stream	If D4.1 = 1, enter "1"	
	Lowest:	No permanently flowing stream	If D4.1 = 0, enter "0"	
Vpools	*Highest:*	Microdepressions in stream	If D49.3 = 1, enter "1"	
	Lowest:	No microdepressions in stream	If D49.3 = 0, enter "0"	
Vlwd	*Highest:*	AU has at least 10 LWD size and decomposition categories	If calculation > = 1.0, enter "1"	
	Lowest:	No categories of LWD	If calculation = 0, enter "0"	
	Calculation:	Scaling based # of categories/10	Enter result of calculation	
	Calculate (D44 + D45)/10 to get result			
			Total of Variable Scores:	
Reducer				
Vphow	pH of standing water < 4.5		If D26.2 < = 4.5, enter "0"	
	pH of standing water >4.5 and < 5.5		If D26.2 > 4.5 and < 5.5, enter "0.5"	
	pH of standing water > =5.5		If D26.2 > = 5.5, enter "1"	
Vupcover	>60% urban or high density residential land use; Or > = 50% clear cut within 1 km		If D3.2 + D3.5 > = 60 or D3.3 > = 50, enter "0.5"	
	At least 30% of area within 1 km in active land uses		If sum (D3.2-D3.6) > = 30, enter "0.8"	
	< 30% area within 1 km in active land uses		If sum(D3.2-D3.6) <30 enter "1"	
			Score for Reducer (Choose Lowest Value)	
Index for Amphibians = Total for variables x reducer x 2.38 rounded to nearest 1				
			FINAL RESULT:	

8.10 Habitat Suitability for Anadromous Fish — Riverine Flow-through Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

8.10.1 Definition and Description of Function

Habitat Suitability for Anadromous Fish in riverine flow-through wetlands is defined as the environmental characteristics that contribute to the refuge and egg-laying needs of anadromous fish species.

The suitability of riverine flow-through wetlands to provide habitat for anadromous fish is modeled by combining variables that represent refuge conditions for the fish during a flood event with one indicative of gravels that can be used for egg laying. Riverine flow-through wetlands are frequently flooded but do not retain the flood-water by definition. This means that anadromous fish have little time to feed in the wetland and do not overwinter there.

The models assess general habitat suitability, not the importance of a wetland to a specific threatened or endangered species, or to a specific regionally important species assemblage. The function is modeled based on the structural elements, physical components, and the characteristics of the AU that are considered to be important elements of habitat for anadromous fish. In general, the suitability of an AU as habitat for anadromous fish is assumed to improve as the number of beneficial habitat characteristics increase.

If the AU is a habitat type that appears to be critical to a specific species, another method is needed to better determine the habitat suitability of that AU [e.g. USFWS Habitat Evaluation Procedures (HEP) USFWS 1980].

8.10.2 Assessing this Function for Riverine flow-through Wetlands

The structural elements of a wetland that are considered to provide refuge are the presence of bars with or without herbaceous vegetation, woody debris, a forest canopy over the stream, and adequate water depth. One variable is used to indicate gravels that can be used for egg-laying.

Habitat Suitability for Anadromous Fish is one of the two habitat functions for which it may be possible to also judge opportunity as part of a rapid assessment method. The Assessment Teams decided that an AU does have the opportunity to provide habitat for anadromous fish if its surface water outlet has a direct connection that is passable by fish to a stream with anadromous fish in it. Information on locations used by anadromous fish is more readily available than for other wildlife. WDFW maintains an extensive database of streams used by anadromous fish, and this can be used as a guide in rating the opportunity. Local sources may also be contacted for information on the presence of anadromous fish.

8.10.3 Model at a Glance

Riverine Flow-through — Habitat Suitability for Anadromous Fish

Process	Variables	Measures or Indicators
Egg laying and refuge for anadromous fish (applies to all variables)	**Vflowmods**	Structures in AU that create low velocity eddies
	Vcover	Number and type of refuge present in water
	V%closurest	% of stream with canopy closure
	Vstreamsubs	Gravel or cobbles present in stream

Index: $\dfrac{\text{2 x Vflowmods + 2 x Vcover + V\%closurest + Vstreamsubs}}{\text{Score from reference standard site}}$

8.10.4 Description and Scaling of Variables

***V**$_{flowmods}$* – The AU has structures on its surface such as large rocks and log jams that modify flows and create eddies on the downstream side. **This variable was judged to be a critical habitat feature in riverine flow-through wetlands and is weighted by a factor of 2.**

> **Rationale**: Water velocities are often higher during floods and small juvenile salmonids can be swept away from their usual overwintering habitats. The presence of large structures in the flow path of floodwaters will create eddies of calmer water on the downstream side. These eddies can provide refuge for the juvenile salmonids.
>
> **Indicators:** No indicators are needed. The presence of large structures on the surface of the AU can be established during the site visit.
>
> **Scaling:** This is an “on/off” variable. AU’s with structures present score a [1]; those without score a [0].

***V**$_{cover}$* – Structures in the AU that provide cover in and over water. This variable is assessed based on three structural elements: 1) vegetation that overhangs permanent streams or channels; 2) undercut banks; and 3) large woody debris in the stream or channel. **This variable is considered to be a critical habitat component and is weighted by a factor of 2 relative to the other variables.**

> **Rationale:** Overhanging vegetation and undercut banks provide both temperature control and protection from predation. McMahon (1983) reported the need for streamside vegetation for shading. Small coho juveniles tend to be harassed, chased and nipped by larger juveniles unless they stay near the bottom, obscured by rocks or logs (Groot and Margolis 1994). Cover for salmonids can be provided by overhanging vegetation, undercut banks, submerged vegetation, submerged objects such s logs and rocks, floating debris, deep water, turbulence and turbidity (Giger 1973). Large woody debris plays an important role in Pacific Northwest streams, creating and enhancing fish habitat in streams of all sizes (Bisson et al. 1987).
>
> **Indicators:** The presence of overhanging vegetation and undercut banks is characterized during the field visit based on presence/absence of certain characteristics as described in Part 2. Direct measures of the quantity and quality of decaying woody debris is not feasible for a rapid assessment method. A descriptive matrix of different sizes and decay levels of woody debris was developed as an indicator for the variable. The matrix is based on the assessment procedure developed for the TFW watershed assessment methods.
>
> **Scaling:** AUs with either overhanging vegetation or undercut banks, and at least 10 categories of large woody debris in permanent open water are scored a [1]. AUs with fewer characteristics are scored proportionally, with each type of cover having equal weight (see Calculation Table 8.10.5). AUs with no types of cover are scored a [0].

***V**$_{\%closurest}$* – The percent of stream length within the AU that has a canopy cover.

Rationale: A canopy over open water provides both temperature control as well as protection from predation. McMahon (1983) reported optimum pool sizes of 10-80 m^2 or 50-250 m^2 for coho production, provided there was enough streamside vegetation for shading. Significant alteration to or removal overhead canopy allows more sunlight to reach across the stream. Direct sunlight, especially in summer can increase water temperatures, in turn affecting aquatic insect composition and growth. High summer water temperatures can kill salmon and trout, increase the incidence of many fish diseases, and alters the feeding activity and body metabolism of fish (Lantz 1971).

Indicators: No indicators are needed for this variable. The percent of stream length within the boundaries of the AU that has a canopy cover can be estimated directly.

Scaling: AU's with 100% of their stream length under a canopy are scored a [1]. Those with less are scored proportionally (%/100).

$\boldsymbol{V_{streamsubs}}$ – Gravels or cobbles are present in the stream within the boundaries of the AU that can be used for egg laying.

Rationale: Some riverine flow-through AUs have a stream within their boundaries. If the stream has exposed gravels or cobbles the salmonids can use the area for egg laying.

Indicators: No indicators are needed. The presence of gravels or cobbles in the AU can be established during the site visit.

Scaling: This is an "on/off" variable. AU's with gravels and cobbles present score a [1]; those without score a [0].

8.10.5 Calculation of Habitat Suitability

Riverine Flow-through – Habitat Suitability for Anadromous Fish

Variable	Description of Scaling		Score for Variable	Result
Vflowmods	*Highest:*	Structures that modify flow	If D40 = 1, enter "2"	
	Lowest:	No structures that modify flow	If D40 = 0, enter "0"	
Vcover	*Highest:*	2 categories of cover present: overhanging vegetation and undercut banks; and 10 or more categories of woody debris on surface and in permanent water	If D32 = 1 and D34 = 1 and (D44 + D45) > = 10 enter "2"	
	Lowest:	No categories of cover present	If D32 + D34 + D44 + D45 = 0, enter "0"	
	Calculation:	Scaled as # of categories of cover normalized by 3	Enter result of calculation	
	If D44 + D45 > = 10 calculate 2/3 x (D32 + D34 + 1); if D44 + D45 < 10 calculate 2/3 x [D32 + D34 +1 + (D44 + D45) / 10]			
V%closurest	*Highest:*	Stream in AU has 100% canopy closure	If D18 = 100, enter "1"	
	Lowest:	Stream in AU has no canopy closure	If D18 = 0, enter "0"	
	Calculation:	Scaled as % of stream length with canopy closure	Enter result of calculation	
	If D18 < 100 calculate D18/100 to get result			
Vstreamsubs	*Highest:*	AU has gravel or cobbles in stream bed	If D49.1 + D49.2 > = 1, enter "1"	
	Lowest:	AU has no gravel or cobbles in stream bed	If D49.1 + D49.2 = 0, enter "0"	
			Total of Variable Scores:	
Index for Habitat Suitability for Anadromous Fish = Total for variables x 1.70 rounded to nearest 1				
			FINAL RESULT:	

8.10.6 Qualitative Rating of Opportunity

The Assessment Teams decided that an AU does have the opportunity to provide habitat for anadromous fish if its surface water outlet has a direct connection that is passable by fish to a stream with anadromous fish in it. Information on locations used by anadromous fish is more readily available than for other wildlife. The Washington State Department of Fish and Wildlife maintains an extensive database of streams used by anadromous fish, and this can be used as a guide in rating the opportunity. Local sources may also be contacted for information on the presence of anadromous fish.

If the AU has an unobstructed passage to a stream or river with anadromous fish it should be rated as having a High opportunity to provide habitat. If there is no passage, or the passage is obstructed, the opportunity is Low.

8.11 Habitat Suitability for Resident Fish — Riverine Flow-through Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

8.11.1 Definition and Description of Function

Habitat Suitability for Resident Fish in riverine flow-through wetlands is defined as the environmental characteristics that contribute to the refuge needs of resident native fish species and the habitat provided by streams within an AU.

The suitability of riverine flow-through wetlands to provide habitat for resident fish is modeled by combining variables that represent refuge conditions for the fish during a flood event with ones indicative of suitable stream habitat. Riverine flow-through wetlands are frequently flooded but do not retain floodwater by definition. This means that resident fish have little time to feed in the wetland outside the permanent stream (if it is contained within the boundaries of the AU).

The model assesses general habitat suitability, not the importance of a wetland to a specific threatened or endangered species, or to a specific regionally important species assemblage. The function is modeled based on the structural elements, physical components, and the characteristics of the wetland that are considered to be important elements of habitat for resident fish. In general, the suitability as habitat is assumed to improve as the number of beneficial habitat characteristics increase.

8.11.2 Assessing this Function for Riverine Flow-through Wetlands

The structural elements of a wetland that are considered to provide refuge are woody debris, a forest canopy over the stream, and adequate water depth. Stream habitat is modeled by the variables representing permanently flowing water and substrates present in the AU.

8.11.3 Model at a Glance

Riverine Flow-through — Habitat Suitability for Resident Fish

Process	Variables	Measures or Indicators
Refuge and stream habitat for resident native fish (applies to all variables)	**Vpermflow**	Presence/absence of flow in channel
	Vcover	Categories of refuge present in water
	V%closurest	% length of stream with canopy closure >75%
	Vstreamsubs	Gravel or cobbles present in stream
	Vwaterdepth	Depths of water in permanent stream
	Index:	$\frac{2 \times Vpermflow + Vcover + V\%closurest + Vstreamsubs + Vwaterdepth}{\text{Score from reference standard site}}$

8.11.4 Description and Scaling of Variables

$V_{permflow}$ – There are channels or streams present in the wetland that have permanently flowing water**. This variable was judged to be a critical habitat feature in riverine flow-through wetlands and is weighted by a factor of 2.**

Rationale: This variable is included for the function because flowing water is an important characteristics for cottids and dace in western Washington (Mongillo pers. comm.).

Indicators: No indicators are needed for this variable in the summer because the presence of flow in a channel can be established directly during the dry season. Indicators for the presence of permanent channel flow in the winter, during the wet season, may be more difficult to establish. Users may have to rely on aerial photographs (usually taken in the summer) or other sources of information to determine if the flows in a channel are permanent.

Scaling: This is an "on/off" variable. An AU scores a [2] if permanent channel flow is present, and a [0] if it is not.

V_{cover} – Structures in the AU that provide cover in and over water. This variable is assessed based on three structural elements: 1) vegetation that overhangs permanent water; 2) undercut banks; and 3) large woody debris in permanent water.

Rationale: Refuge from predators is an important habitat feature for maintaining successful fish populations, and wetlands that provide such refuge have a higher potential of performing than those that do not. Overhanging vegetation and undercut banks provide both temperature control and protection from predation. Large woody debris plays an important role in the Pacific Northwest, creating and enhancing fish habitat (Bisson et al. 1987).

Indicators: The presence of overhanging vegetation and undercut banks is characterized during the field visit based on presence/absence of certain characteristics as described in Part 2. Direct measures of the quantity and quality of decaying woody debris is not feasible for a rapid assessment method. A descriptive matrix of different sizes and decay levels of woody debris was developed as an indicator for the variable. The matrix is based on the assessment procedure developed for the TFW watershed assessment methods.

Scaling: AUs with either overhanging vegetation or undercut banks, and at least 10 categories of large woody debris are scored a [1]. AUs with fewer characteristics are scored proportionally, with each type of cover having a different weight (see Calculation Table 8.11.5). Large woody debris is weighted by a factor of 3 and undercut banks by a factor of 2 relative to overhanging vegetation. AUs with no types of cover are scored a [0].

$V_{\%closurest}$ – The percent of stream length within the boundaries of the AU that has a canopy cover.

Rationale: A canopy over open water provides both temperature control as well as protection from predation for both resident and anadromous fish. Significant alteration to or removal overhead canopy allows more sunlight to reach across the stream. Direct sunlight, especially in summer can increase water temperatures, in turn affecting aquatic insect composition and growth. High summer water temperatures can alter the feeding activity and body metabolism of fish (Lantz 1971).
Indicators: No indicators are needed for this variable. The percent of stream length within the boundaries of the AU that has a canopy cover can be estimated directly.
Scaling: AU's with 100% of their stream length under a canopy are scored a [1]. Those with less are scored proportionally (%/100).

$V_{streamsubs}$ – Gravels or cobbles are present in the stream.

Rationale: Some riverine flow-through wetlands contain a stream within their boundaries. Exposed gravels or cobbles provide habitat for invertebrates that are a major food supply for many native fish species.
Indicators: No indicators are needed. The presence of gravels or cobbles in the AU can be established during the site visit.
Scaling: This is an "on/off" variable. AU's with gravels and cobbles present score a [1]; those without score a [0].

$V_{waterdepth}$ – Depth of water present in permanent stream.

Rationale: Resident fish need a range of water depths for different parts of their life cycles. Shallow waters provide refuge for young fish, while the deeper waters provide refuge for the larger adults. Varying water depths also provide different potential food sources since they are host to different populations of plants and invertebrates.

Indicators: The variable is characterized using a condensed form of the depth classes first developed for WET habitat assessments (Adamus et al. 1987). These are 0-20 cm, 20-100 cm, and > 100 cm.

Scaling: AUs with all three depth classes present are scored a [1]. Those with the two shallower ones are scored a [0.5]; those with 0-20 cm of water are scored a [0.1]. AUs with no permanent or seasonal inundation are scored a [0]. In some cases an AU may have steep sides. If the water depth is greater than 100 cm but the AU does not have enough shallow water to meet the size requirements (0.1 ha or 10%, whichever is the smaller) it is scored a [0.7].

8.11.5 Calculation of Habitat Suitability

Riverine Flow-through – Habitat Suitability for Resident Fish

Variable	Description of Scaling		Score for Variable	Result
Vpermflow	*Highest:*	Permanent channel or stream	If D4.1 = 1, enter "2"	
	Lowest:	No permanent channel	If D4.1 = 0, enter "0"	
Vcover	*Highest:*	Both categories of cover present: overhanging vegetation and undercut banks; and has 10 or more categories of woody debris on surface and in permanent water	If D32 = 1 and D34 = 1 and (D44 + D45) > = 10, enter "1"	
	Lowest:	No categories of cover present	If D32 + D34 + D44 + D45 = 0, enter "0"	
	Calculation:	Scaled as # of categories with the following weights: 1 for overhang, 2 for banks and 3 for LWD normalized to 6	Enter result of calculation	
	If D44 + D45 > = 10 calculate (D32 + 2 x D34 + 3)/6; if D44 + D45 < 10 calculate [D32 + 2 x D34 + 3 x (D44 + D45)/10]/6			
V%closurest	*Highest*	100% canopy closure over stream	If D18 = 100, enter "1"	
	Lowest:	No canopy closure over stream	If D18 = 0, enter "0"	
	Calculation:	Scaled as % of stream length with canopy closure	Enter result of calculation	
	Calculate D18/100 to get result			
Vstreamsubs	*Highest:*	AU has gravel or cobbles in stream bed	If D49.1 + D49.2 > = 1, enter "1"	
	Lowest:	AU has no gravel or cobbles in stream bed	If D49.1 + D49.2 = 0, enter "0"	
Vwaterdepth	*Highest:*	All water depth categories present	If D12.1 + D12.2 + D12.3 = 3, enter "1"	
	High:	Water depths between 0-100 cm present	If D12.1 = 1 **and** D12.2 = 1, enter "0.8"	
	Medium High:	Water depths > 100 cm present	If D12.3 = 1 **and** D12.1 + D12.2 = 0, enter "0.7"	
	Low:	Depths between 0-20 cm present	If D12.1 = 1, enter "0.1"	
	Lowest:	No surface water present	If all D10 = 0, enter "0"	
			Total of Variable Scores:	
Index for Habitat Suitability for Resident Fish = Total for variables x 2.00 rounded to nearest 1				
			FINAL RESULT:	

8.12 Habitat Suitability for Wetland-associated Birds — Riverine Flow-through Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

8.12.1 Definition and Description of Function

Habitat Suitability for Wetland-associated Birds is defined as the environmental characteristics in a wetland that provide habitats or life resources for species of wetland-associated birds. Wetland-associated bird species are those that depend on aspects of the wetland ecosystem for some part of their life needs: food, shelter, breeding, resting. The guilds of wetland-associated birds used as the basis for building the assessment model includes waterfowl, shorebirds, and herons.

In general, the suitability of an AU as bird habitat increases as the number of appropriate habitat characteristics increase. Another assumption used in developing the model is that AUs that provide habitat for the greater number of wetland dependent bird species are scored higher than those that have fewer. **The assessment models are focused on species richness, not on the importance of a wetland to a specific threatened or endangered species or to a specific regionally important guild.**

If the AU is a habitat type that appears to be critical to a specific species, another method is needed in order to determine the habitat suitability of that AU (e.g. USFWS Habitat Evaluation Procedures (HEP), USFWS 1981).

8.12.2 Assessing this Function for Riverine Flow-through Wetlands

The suitability of wetlands in the riverine flow-through subclass as habitat for wetland-associated birds is modeled based on the plant structure, physical components, and the condition of the buffers around the AU. In addition, the models include the scores for other habitat functions that represent prey of birds: namely the habitat suitability index for amphibians, invertebrates, and fish.

AUs that have a closed canopy in the riverine flow-through subclass, however, were judged to **not** have a reduced level of performance because access is provided along the stream corridor. The Assessment Teams judged that the presence of invasive or non-native birds may reduce the suitability of an AU. A variable for this factor was not included in the model because reproducible data on invasive or non-native birds could not be collected during one site visit.

Size is not used as a variable in the equation although it is often cited as an important characteristic of wetlands that provide bird habitat (Richter and Azous in preparation). The question of size is a vexing one, and no satisfactory size thresholds have been identified in the literature that would define the importance of a small versus a large wetland as habitat specific to only wetland-associated birds. Size, however, is incorporated indirectly in the scaling of some of the other variables used. Thus, it is implicit that an AU with a diverse structure is large—small AUs simply cannot contain the same number of different structural elements as large ones.

8.12.3 Model at a Glance

Riverine Flow-through — Habitat Suitability for Wetland-associated Birds

Characteristics	Variables	Measures or Indicators
Feeding, breeding, and refuge for wetland-associated birds (applies to all variables)	**Vbuffcond**	Descriptive table of conditions in buffer
	Vsnags	Categories of snags present
	Vvegintersp	Characteristics of interspersion between vegetation classes - diagrams
	Vspechab	Presence of special habitat features
	Vpow	% permanent open water
	Sinverts	Index for function (H.S. for Invertebrates)
	Samphib	Index for function (H.S. for Amphibians)
	Sfish	Index for higher of two: Anadromous or Resident Fish
	Index:	(Vbuffcond + Vsnags + Vvegintersp + Vspechab + Vpow + Sinverts + Samphib + Sfish)
		Score from reference standard site

8.12.4 Description and Scaling of Variables

***V**$_{buffcond}$* – Condition of buffer within 100 m of the edge of the AU, as rated by extent of undisturbed areas.

Rationale: The condition of the AU buffer affects the ability of the AU to provide appropriate habitat for some guilds (Zeigler 1992). Trees and shrubs provide screening for birds using the AU, as well as providing additional habitat in the buffer itself (Johnson and Jones 1977, Milligan 1985, and Zeigler 1992). The Assessment Teams judged, however, that good buffers are more important in small AUs because wetland-associated birds can use the interior of larger units and not be disturbed.

Indicators: This variable is assessed using the buffer categorization described in the data sheets (Part 2).

Scaling: If the AU is greater than 6 ha, the variable is scored a [1]. Smaller AUs with buffers that are vegetated with relatively undisturbed vegetation of at least 100 m around 95% of the AU (buffer category #5) are scored a [1]. The categories between 0-5 are scaled proportionally as 0, 0.2,0.4, 0.6, and 0.8 respectively. **The size threshold is included so large wetlands are not penalized for having poor buffers**.

***V**$_{snags}$* – The number of different categories of snags, based on decomposition states, found in the AU.

Rationale: Snags are a source of cavities and perches for wetland-associated birds. Several species of birds utilize already existing cavities for nesting and/or refuge locations. The presence of cavities in standing trees can indicate the relative age or maturity of the trees within the AU, and therefore the structural complexity present. Dead wood attracts invertebrates and other organisms of decay, which in turn provide a food source for many species of birds (Davis et al. 1983).

Indicators: The number and size of cavities in an AU cannot be measured directly because they may be difficult to count and measure. Eight different categories of snags representing different levels of decay are used as the indicator for the different potential sizes of cavities. It is assumed that cavities will form or be excavated if dead branches or trunks are present.

Scaling: If a riverine flow-through AU has 6 or more of the 8 categories of snags present it scored a [1]. Fewer categories are scaled as proportional to 6 (i.e. # of categories/6).

***V**$_{vegintersp}$* – The relative interspersion between Cowardin vegetation classes (Cowardin et al. 1979).

Rationale: Vegetation interspersion is the relative position of plant types to one another. As an example, an AU may have an emergent marsh of cattails; a nearby shrub/swamp of willows; and an adjacent area of alder swamp. This AU contains three Cowardin habitat classes: emergent, shrub, and forest. For some bird species, this is irrelevant, as many species are single habitat type users. Other species, though, may require several habitat types to being close proximity to aid their movements from one type to another (Gibbs 1991, and Hunter 1996).
Indicators: The amount of interspersion between vegetation classes is assessed using diagrams developed from those found in the Washington State Rating System (WDOE 1993).
Scaling: AUs with more interspersion between vegetation classes score higher than those with less. The method has four categories of interspersion (none, low, moderate, high) and these are used as the basis for developing a scaled score. A high level of interspersion scores a 1, moderate scores a 0.67, a low scores 0.33, and a category of none scores a 0.

***$V_{spechab}$* –** Special habitat features that are needed or used by aquatic birds. Five different habitat characteristics are combined in one variable:

1) the AU is within 8 km (5 mi) of a brackish or salt water estuary;
2) the AU is within 1.6 km (1 mi) of a lake larger than 8 ha (20 acres);
3) the AU is within 5 km (3 mi) or an open field greater than 16 ha (40 acres);
4) the AU has upland islands of at least 10 sq. m (108 sq. ft.) surrounded by open water (the island should have enough vegetation to provide cover for nesting aquatic birds); and
5) the AU has unvegetated mudflats.

Rationale: The suitability of an AU as habitat for aquatic birds is increased by a number of special conditions. Specifically, the proximity of an AU to open water or large fields increases its utility to migrant and wintering waterfowl. If there is strong connectivity between relatively undisturbed aquatic areas the suitability as habitat is higher (Gibbs et al. 1991, and Verner et al. 1986). In addition, islands surrounded by open water provide a protected nesting area for ducks if they have adequate cover. Mudflats are an important feeding area for migrating birds.

Indicators: No indicators are needed for this variable because the presence of the special habitat features can be determined on site, from maps, or aerial photos.

Scaling: If an AU has 3 or more of the 5 habitat features it is scored a [1]. AUs with two habitat features score a [0.67] for the variable; those with one feature score a [0.33], and those with none score a [0].

V_{pow} – The percent area of the AU that is covered by permanent open water in the form of a stream, channel or river.

Rationale: Permanent open water provides refuge for many species of waterfowl. The presence of open water allows for the establishment of aquatic vegetation beds, which also provides food for different species of waterfowl.

In addition, open water of varying depths provides greater diversity of foraging habitat for a greater variety of water birds (USDI 1978).

The extent of the permanent open water required for different scaled scores is based on an educated guess by the Assessment Team, reflecting the need to provide a rapid method. Areas of open water that are smaller than .1 hectare (1/4 acre), or less than 10% of an AU (if it is < 1 hectare), are difficult to determine from aerial photos..

Indicators: The extent of permanent open water in an AU can be easily determined during the dry summer months and no indicator is needed. There is a problem, however, in establishing the size during the wet season when the AU is flooded to its seasonal levels.

Scaling: AUs with 10%, or more, of their area covered in permanent open water (i.e. stream) are scored a [1] for this variable. AUs with a smaller area are scaled proportionally (%open water/10).

$S_{inverts}$ – The habitat suitability index from the Invertebrate function.

Rationale: The index is used to represent the availability of invertebrates as prey for birds.

Indicators: No indicators are needed. The variable is a index from another function.

Scaling: The index is already scaled between 0 –10, and is re-normalized to a range of 0 - 1.

S_{amphib} – Habitat suitability index for the "amphibian" function.

Rationale: The index is used to represent the availability of amphibians as prey for birds.

Indicators: No indicators are needed. The variable is a index from another function.

Scaling: The index is scaled between 0 –10, and is re-normalized to a range of 0 – 1.

S_{fish} – Habitat suitability index for the Fish function. The assessment methods have two functions to characterize habitat suitability for fish (anadromous and resident). The higher of the two scores is used in this model.

Rationale: The index is used to represent the availability of fish as prey for birds.

Indicators: No indicators are needed. The variable is a index from another function.

Scaling: The index is scaled between 0 –10, and is re-normalized to a range of 0 – 1.

8.12.5 Calculation of Habitat Suitability

Riverine Flow-through – Habitat Suitability for Wetland-associated Birds

Variable	Description of Scaling		Score for Variable	Result
Vbuffcond	*Highest:*	Buffer category of 5 or AU > 6 ha	If D1 > = 6 or, if D42 = 5, enter "1"	
	High:	Buffer category of 4	If D1 < 6 and if D42 = 4, enter "0.8"	
	Moderate:	Buffer category of 3	If D1 < 6 and if D42 = 3, enter "0.6"	
	Medium low:	Buffer category of 2	If D1 < 6 and if D42 = 2, enter "0.4"	
	Low:	Buffer category of 1	If D1 < 6 and if D42 = 1, enter "0.2"	
	Lowest:	Buffer category of 0	If D1 < 6 and D42 = 0, enter "0"	
Vsnags	*Highest:*	At least 6 categories of snags	If calculation > = 1, enter "1"	
	Lowest	No snags present	If calculation = 0, enter "0"	
	Calculation:	Scaled as # categories/6	Enter result of calculation	
	Calculate D31/6 to get result			
Vvegintersp	*Highest:*	High interspersion	If D39 = 3, enter "1"	
	Moderate:	Moderate interspersion	If D39 = 2, enter "0.67"	
	Low:	Low interspersion	If D39 = 1, enter "0.33"	
	Lowest:	No interspersion (1 class only)	If D39 = 0, enter "0"	
Vspechab	*High:*	> = 3 of 5 special habitat features	If (D8.5 + D27 + D28 + D29 + D33) > = 3, enter "1"	
	Medium high:	2 of 5 special habitat features	If (D8.5 + D27 + D28 + D29 + D33) > = 2, enter "0.67"	
	Medium low:	1 of 5 special habitat features	If (D8.5 + D27 + D28 + D29 + D33) = 1, enter "0.33"	
	Lowest:	No special habitat features	If (D8.5 + D27 + D28 + D29 + D33) = 0, enter "0"	
Vpow	*Highest*	> =10% permanent open water	If calculation > = 1, enter "1"	
	Lowest:	No permanent open water	If calculation = 0, enter "0"	
	Calculation:	Scaled as % open water/10	Enter result of calculation	
	Calculate D8.3/10 to get result			
Sinverts	*Scaled score:*	Index for Invertebrates	Index of function/10	
Samphib	*Scaled score:*	Index for Amphibians	Index of function/10	
Sfish	*Scaled score:*	Index for Anadromous Fish; or Index for Resident Fish	Index of Anadromous Fish/10; or Index of Resident Fish/10 (use higher of two scores)	
			Total of Variable Scores:	
Index for Habitat Suitability for Wetland-associated Birds = Total for variables x 1.66 rounded to nearest 1				
			FINAL RESULT:	

8.13 Habitat Suitability for Wetland-associated Mammals — Riverine Flow-through Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

8.13.1 Definition and Description of Function

Habitat Suitability for Wetland associated mammals is defined as wetland features and characteristics that support life requirements of four aquatic or semi-aquatic mammals. Mammalian species whose habitat requirements were modeled are the beaver (*Castor canadensis*), muskrat (*Ondatra zibethicus*), river otter (*Lutra canadensis*), and mink (*Mustela vison*).

The model for this function is based on general habitat requirements for each of the four wetland-associated mammals. The model reflects the suitability of an AU to support mammal richness rather than individual species abundance. Habitat considerations in the model are restricted to the condition of the wetland buffer, and characteristics that can be found within the AU itself. It is assumed that wetlands that provide habitat for all four of the aquatic mammal species function more effectively than ones that meets the habitat needs of fewer species.

Wetlands that are found within urban or residential areas are modeled as having a reduced level of performance. Adjacent areas that are developed provide an avenue for humans, cats, dogs, and other domestic animals to harass mammal populations.

The SWTC and Assessment Teams decided to focus the model specifically on the aquatic fur-bearing mammals because these are wetland dependent species that are important to society, and they represent different types of mammals that use wetlands. Many terrestrial mammals will use wetlands, if they are available, to meet some of their life maintenance requirements. These species, however, do not need wetlands. It would have been too difficult to develop a mammal model that incorporates habitat features for all mammals using wetlands. Such models would have had to incorporate too much information about the surroundings uplands and expanded the scope of the assessment methods to the extent that they would no longer be considered "rapid."

If the AU is a habitat type that appears to be critical to a specific species, another method is needed in order to determine the habitat suitability of that AU (e.g. USFWS Habitat Evaluation Procedures (HEP), USFWS 1981).

8.13.2 Assessing this Function for Riverine Flow-through Wetlands

The suitability of wetlands in the riverine flow-through subclass as mammal habitat is modeled by buffer conditions, water depths, presence of open water, connectivity of the site to other suitable habitat, interspersion of vegetation and open water, and the presence of characteristics important to each species modeled. The index for the fish habitat function is added as a variable to reflect the importance fish have in the diet of otters and, to a lesser degree, mink. Reduction in suitability is modeled based on the percentage of the surrounding landscape, within 1 km, that is developed ($V_{upcover}$).

8.13.3 Model at a Glance

Riverine Flow-through — Habitat Suitability for Wetland-associated Mammals

Characteristics	Variables	Measures or Indicators
Breeding, feeding and refuge for beaver, mink, otter, and muskrat (applies to all variables)	**Vbuffcond**	Descriptive table of buffer conditions
	Vwaterdepth	Number of water depth categories present
	Vcorridor	Categorical rating of corridor
	Vbrowse	Area of woody vegetation for beaver
	Vemergent2	At least .25 ha of emergent vegetation
	Vbank	Banks present of fine material
	Vpermflow	AU has channel with permanent flowing water
	Sfish	Index for higher of two: Anadromous or Resident Fish
Reducers		
Development	**Vupcover**	Land uses within 1 km of AU
Index:		(Vbuffcond + Vwaterdepth + Vcorridor + Vbrowse + Vemergent2 + Vbank + Vpermflow + Sfish) x (Vupcover) / Score from reference standard site

8.13.4 Description and Scaling of Variables

$V_{buffcond}$ – Land-use patterns within 100 m of the edge of the AU.

Rationale: A relatively undisturbed buffer serves to minimize disturbance (Burgess 1978, Allen and Hoffman 1984), provide habitat for prey species and food sources for mammals (Brenner 1962, Dunstone 1978, Allen 1983), cover from predators (Melquist et al. 1981), and den sites for resting and reproduction for wetland-associated mammals (Allen 1983). Both live standing vegetation and dead decaying plant material are important components of good buffer conditions.

Indicators: This variable is assessed using the buffer categorization described in the data sheets in Part 2.

Scaling: AUs with buffers that are vegetated with relatively undisturbed plant communities of at least 100 m around 95% of the AU (buffer category #5) are scaled a [1]. The categories between 0-5 are scaled proportionally as 0, 0.2,0.4, 0.6, and 0.8 respectively.

$V_{waterdepth}$ – The varying depths of water present in the stream of an AU during the dry season.

Rationale: Adequate water depth is an essential criterion for beaver and muskrat. These aquatic rodents are vulnerable to predation when water depths are shallow. Declines in water level expose lodge or bank burrow entrances to predators. Further, permanent water conditions increase the potential for a resident fish population which serves as a stable food supply for mink and river otters.

Indicators: The variable is scored using a condensed form of the depth classes developed for WET habitat assessments (Adamus et al. 1987). These are 0-20 cm, 20-100 cm, and >100 cm.

Scaling: AUs with water depths greater than 1 m in permanent streams are scored a [1] for this variable. Those with water depths between 1-100 cm are scored a [0.5]; those with depths between 1-20 cm are scored a [0.3]; and those with water depths less than 1 cm, or no water at all, are scored a [0].

$V_{corridor}$ – The type of vegetated connections present between the AU and other nearby habitat areas.

Rationale: This variable characterizes the connection of the AU to other relatively undisturbed areas capable of providing mammal habitat. Adolescent mammals born and raised within an AU use natural riparian corridors to move from their natal area to unoccupied habitat. Riparian corridors that have relatively undisturbed vegetation cover ensure that dispersing animals are capable of reaching and populating or repopulating unoccupied habitat. Further, mink and river otter have a number of core activity areas within a larger home range. A loss of adequate travel corridors between core activity areas has potential to restrict or eliminate mammal use if the area of suitable habitat drops below required levels.

Indicators: This variable is determined using a modified corridor rating system developed in the Washington State Rating System (WDOE 1993.) Corridors are rated on a scale of 0-3 (Part 2).

Scaling: AUs rating a 3 for their corridor connections are scored a [1] for this variable. Those with a rating of 2 are scored [0.67]; those with a rating of 1 are scored [0.33]; and those with a rating of 0 are scored [0].

V_{browse} – This variable characterizes the presence of woody deciduous plants that beavers prefer as a primary food source.

Rationale: Woody deciduous species commonly used by beaver include willow (*Salix spp*.), aspen (*Populus tremuloides*) cottonwood (*Populus spp.*) (Denney 1952). Trees and shrubs closest to the AU edge are generally used first (Brenner 1962). In a California study, 90% of all cutting of woody material was within 100 feet of the AU edge (Hall 1970). Red alder (*Alnus rubra*) is also a common food source in the lowlands of western Washington.

Indicators: This variable is determined by estimating the amount of alder, willow, aspen and cottonwood within the AU, and/or within a 100 m buffer around the AU.

Scaling: This is an "on/off" variable. AUs with more than 1 hectare (2.5 acres) of willow, aspen, or cottonwood in them or in their buffer will score a [1]. AUs with less will score a [0]. The size is threshold based on the data collected during the field calibrations and the judgements of the Assessment Teams regarding suitable beaver habitat. Literature for areas outside the Pacific Northwest suggests that much larger areas are needed to sustain a beaver family (Denney 1952), but the Assessment Teams judged these numbers were not appropriate.

$V_{emergent2}$ – Emergent plants in the AU covering more than 0.4 ha (1 acre).

Rationale: Muskrat and beaver use persistent emergent cover for security and feeding (Errington 1963, Jenkins 1981). Muskrats also use this vegetation as material for lodge construction (Wilner et al. 1980). Allen (1983) believes that beaver prefer herbaceous vegetation over woody vegetation during all seasons, if available.

Indicators: This variable is estimated using the Cowardin vegetation class "emergent" as an indicator of the amount of persistent emergent vegetation used by the mammals.

Scaling: This is an "on/off" variable. AUs with an area of emergent vegetation that is larger than 0.4 ha score a [1] for the variable. AUs that do not meet this criterion score a [0]. AUs need to have a minimum of 0.4 ha in emergent cover to score for this variable. Muskrats appear to prefer the greatest of aerial coverage in emergent cover. The size threshold is based on the judgement of the Assessment Teams. 0.4 ha is considered to be the minimum necessary to maintain a family of muskrats or beaver.

V_{bank} – This variable identifies the presence of slope and soil conditions that are suitable for muskrat, otter, and beaver bank burrows.

Rationale: When studying bank burrowing muskrats, Earhart (1969) found that a minimum bank slope of 10° was required before burrows were consistently observed regardless of soil type. Gilfillan (1947) considered 30° or more slope as optimum conditions for muskrat bank burrows when the bank height exceeds 0.5 meters (1.6 feet). Muskrat and beaver are capable of constructing bank burrows in a wide range of soil conditions. Muskrat studies by Errington (1937) and Earhart (1969) note that clay soils provide the most suitable substrate for burrow excavation, but even soils with high sand content may provide suitable burrowing sites if dense vegetation exists (Errington 1937). Beaver are capable of constructing lodges against a bank or over the entrance of a bank burrow (Allen 1983) and appear to have less specific slope and soil type limitations for bank burrows.

Indicators: No indicators are needed to assess this variable. The presence of banks can be determined during the site visit. . A steep bank that can be used for denning must be 1) > 30 degrees 2) more than 0.6 m (2 ft.) high (vertical), 3) of fine material such as sand, silt, or clay.

Scaling: This is an "on/off" variable. AUs meeting the criteria for banks are scored a [1] for the variable. Those with no banks are scored a [0].

$V_{permflow}$ – Channels or streams present in the AU with permanently flowing water.

Rationale: This variable is included in the model because flowing water is an important characteristic for otters. In addition, the presence of permanent flowing water is an indicator that a surface water connection exists that will facilitate the dispersal of wetland-associated mammals living in the AU.

Indicators: No indicators are needed for this variable in the summer because the presence of flow in a channel can be established directly in the summer during the dry season. Indicators for the presence of permanent channel flow in the winter, during the wet season, may be more difficult to establish. Users may have to rely on aerial photographs (usually taken in the summer) or other sources of information to determine if the flows in a channel are permanent.

Scaling: This is an "on/off" variable. An AU scores a [1] if permanent channel flow is present, and a [0] if it is not.

S_{fish} – Habitat suitability index from the "fish" function. The assessment methods have two functions to characterize habitat suitability for fish (anadromous and resident). The higher of the two scores is used in this model.

Rationale: This variable is specific to river otter and to a lesser extent for mink. Melquist and Hornocker (1983) found fish to be the most important prey of otters studied over a four year period. Annually, fish occurring in 93-100% of the 1,902 scats analyzed this Idaho study. Mink exhibit considerable variation in their diet, according to season, prey availability, and habitat type (Wise et al. 1981, Linscombe et al. 1982, and Smith and McDaniel 1982). In an Idaho study, fish occurred more frequently (59%) in the diet of mink than any other prey category. However, Eberhardt and Sargeant (1977) reported that mink in North Dakota AUs, which do not support fish, preyed heavily on birds and mammals.

Indicators: No indicators are needed. The variable is a index from another function.
Scaling: The index is scaled between 0 –10, and re-normalized to a range of 0 – 1. The higher of the two scores for fish (resident or anadromous) is used to characterize the potential for fish as a food source.

$V_{upcover}$ – The types of land uses within 1 km of the estimated AU edge. This variable is used to indicate potential reductions in the level of performance for the function.

Rationale: Human alteration to the AU buffer has direct impacts to the AUs habitat suitability for mammals. These alterations also include the associated negative impacts from harassment by humans and domestic animals. Loss or alteration of the natural areas around an AU has direct adverse impacts to feeding, loafing, and breeding habitat for mink, river otter, and muskrat and beaver. These mammals are vulnerable to harassment and predation by domestic pets (Errington 1937, Slough and Sadleir 1977, Burgess 1978, and Melquist and Hornocker 1983). This variable is in contrast to ***$V_{buffcond}$***, which gives a positive value rating to buffers in good condition. Two variables were needed to represent upland conditions because ***$V_{buffcond}$*** does not address the issue of disturbances to mammals from specific adjacent land uses.
Indicators: No indicators are needed to assess this variable. The amount and type of land uses within 1 km of the AU can be established from aerial photographs or site visits.
Scaling: AUs with at least 15% of their surrounding land in urban land uses, or at least 20% high density residential use, or at least 40% low density residential land use, have their index for the function reduced by a factor of 0.7.

8.13.5 Calculation of Habitat Suitability

Riverine Flow-through — Habitat Suitability for Wetland-associated Mammals

Variable	Description of Scaling		Score for Variable	Result
Vbuffcond	*Highest:*	Buffer category of 5	If D42 = 5, enter “1”	
	High:	Buffer category of 4	If D42 = 4, enter “0.8”	
	Moderate:	Buffer category of 3	If D42 = 3, enter “0.6”	
	Medium low:	Buffer category of 2	If D42 = 2, enter “0.4”	
	Low:	Buffer category of 1	If D42 = 1, enter “0.2”	
	Lowest:	Buffer category of 0	If D42 = 0, enter “0”	
Vwaterdepth	*Highest:*	Water depths >1 m present	If D12.3 = 1, enter “1”	
	Moderate:	Water depths between 1-100 cm present	If D12.1 and D12.2 = 1, enter “0.5”	
	Low:	Depths between 1-20 cm present	If D12.1 = 1, enter “0.3”	
	Lowest:	No surface water present	If all D10 are 0, enter “0”	
Vcorridor	*Highest:*	Corridor rating is 3	If D43 = 3, enter “1”	
	Moderate:	Corridor rating is 2	If D43 = 2, enter “0.67”	
	Low:	Corridor rating is 1	If D43 = 1, enter “0.33”	
	Lowest:	Corridor rating is 0	If D43 = 0, enter “0”	
Vbrowse	*Highest:*	>1 hectare of beaver’s preferred veg. in and within 100 m of AU	If D30 = 1, enter “1”	
	Lowest:	Does not have the above	If D30 = 0, enter “0”	
Vemergent2	*Highest:*	Emergent cover that is > = 0.4 ha	If (D1 x D14.5)/100 > = 0.4, enter “1”	
	Lowest:	No emergent cover or emergents = < 0.4 ha	If (D1 x D14.5)/100 < 0.4, enter “0”	
Vbank	*Highest:*	Steep banks suitable for denning	If D37 = 1, enter “1”	
	Lowest:	Above not present	If D37 = 0, enter “0”	
Vpermflow	*Highest:*	Channel with permanent water	If D4.1 = 1, enter “1”	
	Lowest:	No channel present	If D4.1 = 0, enter “0”	
Sfish	*Scaled score:*	Index for Anadromous Fish; or Index for Resident Fish	Index for Anadromous Fish / 10; or Index for Resident Fish / 10 (use higher of two scores)	
______________			**Total of Variable Scores:**	
Reducer				
Vupcover	Land use within 1 km > = 15% urban commercial, or > = 20% high density resid.; or > = 40% low density resid.		If D3.4 > = 15 OR D3.5 > = 20 or D3.6 > = 40, enter “0.7”	
	Land use criteria described above not met		If above not met, enter “1”	
			Score for Reducer:	
Index for Habitat Suitability for Wetland-associated Mammals = Total for variables x reducer x 1.47 rounded to nearest 1				
			FINAL RESULT:	

8.14 Native Plant Richness — Riverine Flow-through Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

8.14.1 Definition and Description of Function

Native Plant Richness is defined as the degree to which a wetland provides a habitat for a relatively high number of native plant species.

An AU is judged to provide habitat for native plants if it contains a diverse group of native plants. This function is the only one for which an actual estimate of performance can be made because the number of plant species can be estimated during a single site visit. Many native plants are persistent and can be documented in a rapid assessment method. The assessment of species richness during the site visit is used as a surrogate for the total richness. If an AU contains a diverse and mature assemblage of native plants it is assumed to perform the function at a high level. Those lacking diverse native plant assemblages and structure are assumed to perform the function at a lower level.

Note: The assumption is valid only if the AU has **not** been recently cleared or altered. If you find the AU has been recently cleared or cut, the index from the model will not provide an adequate assessment of the function.

The Assessment Teams considered using the list of native plant communities developed by Kunze (1994) for western Washington as the basis for the assessment. Attempts to identify the specific plant associations by name, however, proved to be too difficult for most investigators not specifically trained as botanists or plant ecologists.

The Assessment Teams also judged that AUs where one or more of the dominant species is non-native have lost some of their ability to support native plant associations. Non-native plants that become dominant tend to form monocultures that exclude native species. **The percent of the AU dominated, or co-dominated, by non-native species is modeled as a reducer of habitat**.

Note: A variable representing invasive **native** species was considered as a reducer. The Assessment Teams, however, decided that the impact of invasive native species was, to some degree, addressed in other variables ($V_{prichness}$, V_{assoc}, and V_{strata}). The presence of a native invasive species is reflected in lower scores for those variables. The Assessment Teams judged the presence of non-native species as more detrimental to the performance of this function, and a element of the wetland ecosystem that needed to be highlighted.

8.14.2 Assessing this Function for Riverine Flow-through Wetlands

The richness of native plants in the riverine flow-through subclass is assessed by the richness of the existing plant species and associations. Variables include the number of plant associations in the AU, the richness of plant species, and structural elements such as number of strata and the presence of mature trees.

8.14.3 Model at a Glance

Riverine Flow-through — Native Plant Richness

Process	Variables	Measures or Indicators
Native plant species	**Vstrata**	Number of strata present in any plant association
	Vassemb	Number of plant assemblages
	Vmature	Presence/absence of mature trees
	Vnplants	Number of native plant species
Reducers		
	Vnonnat	% of AU dominated by non-native plant species
	Index:	(Vstrata + Vassemb + Vmature + Vnplants) x (Vnonnat) / Score from reference standard site

8.14.4 Description and Scaling of Variables

V_{strata} – The maximum number of strata in any single plant association. A plant association can have up to 6 strata (layers: trees, shrub, low shrub, vine, herbaceous, moss). To count as a stratum, however, the plants of that stratum have to have 20% cover in the association in which it is found.

> **Rationale:** Each stratum of a plant association is composed of different plant species. AUs with more strata, therefore, have the potential to support more native plant species than ones with fewer. The number of strata is used as an indicator of plants richness that can be associated with each specific strata that may not be counted during the site visit. These include many mosses and other bryophytes that are not included in a species count.
>
> **Indicators:** No indicators are needed to assess this variable. The number of strata can be estimated directly at the site.
>
> **Scaling:** AUs with 5 or 6 strata are scored a [1] for this variable. AUs with only one are scored a [0.2]. AUs with 2-4 strata are scaled proportionally as 0.4, 0.6, and 0.8 respectively. For this function, the vine stratum is not counted if dominated by non-native blackberries.

V_{assemb} – The number of plant assemblages in the AU.

Rationale: Each plant assemblages represents a different group of plant species. Even if some plant species are the same between associations, the ecological relationships between the species within the associations are probably different, and represent potential differences in phenotypes. The number of associations, therefore, is one way to characterize the richness of plants in an AU. The procedures for collecting data described in Part 2 provide guidance on how to identify associations in the field.

Indicators: No indicators are needed to assess this variable. The number of associations can be determined in the field.

Scaling: Riverine flow-through AUs with 10 or more plant associations are scored a [1]. AUs with fewer are scaled proportionally.

V_{mature} – The AU has, or does not have, a stand of mature trees present.

Rationale: The model is giving a point for the presence of a stand of mature trees. A mature stand is used as a surrogate for stability, complexity and structure in plant associations that may not be captured by other variables. The presence of mature trees suggests the AU may contain native plant species that are intolerant of much disturbance and that might not be observed because of their scarcity.

Indicators: This variable is characterized by measuring the dbh (diameter at breast height) of the five largest trees of specific species (see Part 2 for list of species and size criteria). If the average diameter of the three largest of a given species exceed the diameters given in Part 2, the AU is considered to contain a stand of mature trees.

Scaling: This is an "on/off" variable. AUs with mature trees are scored a [1], those without are scored a [0].

$V_{nplants}$ – The number of native plant species present.

Rationale: The number of native plant species assessed during one site visit is one measure of how effective an AU is at providing a diverse habitat for native plants and maintaining regional plant biodiversity. It is not possible, however, to determine the total species richness in one visit and within a few hours. Some plants are annuals and grow for only a short time, others have a very limited distribution and may occupy a small and inconspicuous patch that is easily overlooked. For this reason the count of native species determined during the site visit is only an indicator of the actual number present.

Indicators: The indicator of overall native plant richness is the number of native species found during the site visit.

> The Assessment Teams recognize that observations made during the summer may result in a higher count of plant species than in the winter. This question remains unresolved as most of the calibration occurred during the summer and fall. A different scaling may be developed for winter and summer if further data necessitates.

Scaling: If the AU has 30 or more native species it is scored a [1]. AUs with a fewer number of native species are scaled proportionally (# of native species/30).

$V_{nonative}$ – The percent of the AU where non-native species are dominant or co-dominant (non-native species are listed in Part 2, Appendix L) **This is a variable of reduced performance.**

Rationale: The Assessment Teams judged that wetlands where one or more of the dominant species is non-native have lost some of their potential for maintaining native regional plant biodiversity. Non-native plants that become dominant tend to exclude many of the less common native plants.

Indicators: No indicator is needed for this variable. The areal extent of non-native species can be determined in the field.

Scaling: AUs where non-native species extend over more than 75% of the AU have their score reduced by a factor of 0.5. Those with an extent of 50 – 75% are reduced by a factor of 0.7, and those with an extent of non-native between 25-49% are reduced by a factor of 0.9. AUs where non-native species are dominant or co-dominant on less than 25% of the AU do not have their score reduced.

8.14.5 Calculation of Habitat Index

Riverine Flow-through – Native Plant Richness

Variable	Description of Scaling		Score for Variable	Result
Vstrata	*Highest:*	5 strata present (no blackberries)	If D21-D21.1 = 5, enter "1"	
	High:	4 strata present "	If D21-D21.1 = 4, enter "0.8"	
	Moderate:	3 strata present "	If D21-D21.1 = 3, enter "0.6"	
	Medium Low:	2 strata present "	If D21-D21.1 = 2, enter "0.4"	
	Low:	1 stratum present "	If D21-D21.1 = 1, enter "0.2"	
	Lowest:	Blackberries only stratum	If D21-D21.1 = 0, enter "0"	
Vassemb	*Highest:*	At least 10 plant assemblages	If calculation > = 1, enter "1"	
	Lowest:	One plant assemblage present	If calculation < = 0.11, enter "0.1"	
	Calculation:	Scaling based on the number of assemblages divided by 10	Enter result of calculation	
	Calculate D20/10 to get result			
Vmature	*Highest:*	Mature trees present	If D22 = 1, enter "1"	
	Lowest:	No mature trees present	If D22 = 0, enter "0"	
Vnplants	*Highest:*	# of native plant species > = 30	If calculation > = 1, enter "1"	
	Lowest	One or less native plant species	If calculation < = 0.04, enter "0"	
	Calculation:	Scaled as # of native species/30	Enter result of calculation	
	Calculate (D19.1)/30 to get result			
			Total of Variable Scores:	
Reducer				
Vnonnat	>75% cover of non-native plants		If D24.1 = 1, enter "0.5"	
	50-75% cover of non-native plants		If D24.2 = 1, enter "0.7"	
	25 - 49% cover of non-native plants		If D24.3 = 1, enter "0.9"	
			Score for Reducer	
Index for Native Plant Richness = Total for variables x reducer x 2.94 rounded to nearest 1				
			FINAL RESULT:	

8.15 Potential for Primary Production and Organic Export — Riverine Flow-through Wetlands

Note: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

8.15.1 Definition and Description of Function

The function of Primary Production and Organic Export is defined as wetland processes that result in the production of plant material and its subsequent export to surface waters.

Wetlands are known for their high primary productivity (variously expressed as gm-Carbon/m^2 /year or as total biomass) and the subsequent export of organic matter to adjacent aquatic ecosystems (Mitch and Gosselink 1993). In some cases, wetlands may be highly productive, but most of the organic material produced is retained within the wetland where it originates (e.g. high salt marshes or coniferous forests). Alternatively, in some wetlands production may be lower, but most of it is exported (e.g. riverine marshes). **Performance of this function requires both that organic material is produced and a mechanism is available to move the organic matter to adjacent or contiguous aquatic ecosystems**. The exported organic matter provides an important source of food for most downstream aquatic ecosystems (Mitch and Gosselink 1993).

8.15.2 Assessing this Function for Riverine Flow-through Wetlands

The potential of an AU in the riverine flow-through subclass to produce and export organic matter is modeled only as the production of organic materials. The export of organic material out of the AU is assumed to be the same for all wetlands in the subclass because they are frequently flooded.

Amount of production is most directly related to presence of plant cover ($V_{vegcover}$). Variables are then added to reflect type of vegetation ($V_{non\text{-}evergreen}$ *and* $V_{understory}$). The vegetation variables are not chosen to reflect higher rates of primary production, rather they reflect types of vegetation that decompose more readily. Although there seems to be a commonly held hypothesis that herbaceous vegetation is more productive than woody vegetation, the literature is inconclusive on this issue. For example, evergreen coniferous forests (e.g. hemlock) can be as productive as some of the most productive herbaceous sites (e.g. cattail marshes) (Franklin and Dyrness 1973, Mitch and Gosselink 1993). Other literature simply records high production for systems described as “marshes and swamps” without distinguishing based on vegetative cover type.

The principal reason for adding a variable to reflect vegetation type is to capture the variability in rate of decomposition of the organic matter produced, and, therefore, the ease of export. The model recognizes that herbaceous and deciduous plant material is easily decomposed and much of the above ground annual production is available for export as dissolved organic matter.

The equation is structured so that an AU receives a basic score based on the percent of the AU that is vegetated ($V_{vegcover}$). The score is increased if part of that total vegetation is either herbaceous, aquatic bed, or deciduous woody to reflect the less refractory nature of these vegetation types. The model assumes that non-deciduous (evergreen) coniferous needles are the most refractory and least usable by adjacent ecosystems (even toxic in some cases). Thus no additions to the score are made for presence of conifer cover. An additional variable is included to model the herbaceous understory that may be present in a forested or scrub/shrub Cowardin vegetation classes, since the understory is an additional source of labile organic matter.

No riverine wetlands were found with a bog component that was more than 25% of the AU. There was no need, therefore, to include a score reducer for this subclass.

8.15.3 Model at a Glance

Riverine Flow-through — Potential for Primary Production and Organic Export

Process	Variables	Measures or Indicators
Primary production (applies to all variables)	**Vvegcover**	% of AU with vegetation cover
	Vnon-evergreen	% area of all non-evergreen vegetation
	Vunderstory	% area of herbaceous understory in AU
	Index:	(Vvegcover + Vnon-evergreen + Vunderstory) / Score from reference standard site

8.15.4 Description and Scaling of Variables

$V_{vegcover}$ **–** The percent of the total area of the AU is covered by plants.

Rationale: The assumption made by the Assessment Teams is that the average amount of primary production per acre in an AU is most directly related to the amount of its total plant cover.
Indicators: No indicators are needed for this variable. The areal extent of vegetation can be determined from field visits or aerial photographs.
Scaling: An AU that is completely vegetated (100% of AU) is scored a [1]. AUs where the vegetated areas is less, because of open water or mudflats, are scored proportionally (%area/100).

$V_{non-evergreen}$ **–** The percent of the AU that is dominated by deciduous (non-evergreen) vegetation (emergent, deciduous forest, deciduous scrub/shrub, and aquatic bed).

Rationale: This variable is chosen to reflect the types of vegetation that decompose more readily and are, therefore, more exportable.
Indicators: The indicator for this variable is the area that would be classified as emergent, deciduous forest, deciduous scrub/shrub, and aquatic bed using the Cowardin classification (Cowardin et al. 1979).
Scaling: An AU that is completely vegetated with emergent, deciduous forest, deciduous scrub/shrub, and aquatic bed (100% of area when all are added together) is scored a [1]. AUs where the total area of these vegetation classes is lower are scored proportionally (total %area/100).

$V_{understory}$ **–** Percent of the AU where an herbaceous understory provides at least a 20% cover under areas of forest or scrub/shrub vegetation classes.

Rationale: An additional variable is included to model the herbaceous understory that may be present in a forested or scrub shrub Cowardin vegetation class. The understory is an additional source of labile organic matter that is not captured in the other vegetation variables.
Indicators: No indicators are needed. The % areal extent of herbaceous understory is estimated during the field visit.
Scaling: If 100% of the AU has an herbaceous understory it is scored a [1]. AUs where understory is less are scored proportionally (% area/100).

8.15.4 Calculation of Potential Performance

Riverine Flow-through – Primary Production and Organic Export

Variable	Description of Scaling		Score for Variable	Result
Vvegcover	*Highest:*	AU is100% vegetated	If calculation = 1, enter "1"	
	Lowest:	AU has minimal vegetation cover	If calculation < = 0.05, enter "0"	
	Calculation:	Scaled as % vegetated/100	Enter result of calculation	
	Calculate sum (D14.1 to D14.6) /100 to get result			
Vnonevergreen	*Highest:*	100% of AU has cover of non-evergreen vegetation	If calculation = 1, enter "1"	
	Lowest:	AU has only evergreen vegetation	If calculation = 0, enter "0"	
	Calculation:	Scaled as a fraction based on % area	Enter result of calculation	
	Calculate (D14.2 + D14.4 + D14.5 + D14.6) / 100 to get result			
Vunderstory	*Highest:*	Understory 100% herbaceous	If calculation = 1, enter "1"	
	Lowest:	AU has no understory	If D16 = 0, enter "0"	
	Calculation:	Scaling based on understory as % of the total area of AU	Enter result of calculation	
	Calculate (0.01 x D16) x (D14.1 + D14.2 + D14.3 + D14.4)/100			
			Total of Variable Scores:	
Index for Primary Production and Export = Total x 3.33 rounded to nearest 1				
			FINAL RESULT:	